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TEMPER

TECHNOLOGICAL,
ECONOMIC,
MILITARY AND
POLITICAL
EVALUATION
ROUTINE

AS AD 10. 471458

Volume II

THE THEORY OF THE MODEL

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25 August 1965

TEMPER

VOLUME II

THE THEORY OF THE MODEL

Contract No. DA 49 - 146 - XZ - 110

Prepared under the direction of the

NATIONAL MILITARY COMMAND SYSTEM
SUPPORT CENTER

for the

JOINT WAR GAMES AGENCY

by the

Raytheon Company
Bedford, Massachusetts

"The views, conclusions, or recommendations expressed in this document do not necessarily reflect the official views or policies of the Department of Defense."

FOREWORD

The TEMPER program was initially funded by Raytheon Company and received continued support through Contract No. DA49-146-XZ-110 under the direction of The National Military Command System Support Center (NMCSSC) of The Defense Communication Agency for the Joint War Games Agency. The project was conceived by and initially developed at Raytheon under the direction of Clark C. Abt. The principal contributors to the project were Robert L. Goodrich, Morton Gorden, James C. Hodder, Robert V. Jacobson, Walter F. Jaros, Joanne Lewis, John J. McDonnell, Robert Nelson, Peter Miller, Anton S. Morton, Thomas C. O'Sullivan, Ernest Rogers, Warren Siemens and Ellen Wax. From the early days of the project, personnel from the Joint War Games Agency and the NMCSSC have lent their encouragement and offered their guidance. Particular mention should be made of Col. W. T. Minor, Col. William Jones (Ret.), Lt. Col. Andrew Keller (Ret.), Lt. Col. James Sherwood, and Capt. George Draper.

Volume I gives a broad view of TEMPER to determine if it is applicable to a potential user's problem. Volume II provides details of the simulation and the theory. Volume III describes how to set up, play, and analyze a game. (It is recognized that Volume III falls far short of being a game handbook. The lack of gaming experience, time, and money, prevented development to that point. It is expected that with time and experience the material in Volume III can be developed into a handbook in the full sense of the term). Volume IV which follows the outline of Volume II gives details of the computer program including numerical examples of each element of the simulation. Volume V is a computer operator's reference for setting up, debugging, and running a game. Volume VI is a reference directory which defines variables and parameters and gives their use. A seventh volume, not a part of the formal documentation, presents raw data collected for a 1960 data base and is available as a guide for collecting future data bases.

Project director has been, in order of their service, Clark C. Abt, James C. Hodder, and Thomas C. O'Sullivan, Jr.

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INTRODUCTION

This document describes the theory of the TEMPER model and the operation of the TEMPER computer simulation. The TEMPER simulation has been designed to provide an analytic tool for the study of global cold war conflict. The design of the model reduces the totality of the world to 39 Nation-Groups in 13 land conflict regions and seven seas. Each Nation-Group has physical characteristics such as size, GNP, and military forces; motivations such as propensity to use armed forces in times of crisis; and international relations with friendly nations. Internal economic activity and international trade are simulated. Each Nation-Group perceives a world which may be at variance with its concept of an ideal world. The model assumes that it will take rational steps (although possibly of an inappropriate magnitude) to reduce the variance between the perceived and ideal world. These actions may be in conflict, and Nation-Groups respond to the threats these conflicts bring about. The user can adjust the TEMPER simulation to focus on a particular region and problem. By trying different values for key variables, he can gain insight into the complex interactions of the real world; in substance he can perform experiments, not with the real world, but with a model which is a simplified replica of the real world.

Details of the techniques for using the TEMPER simulation are given in Volume III, Game Handbook, together with a detailed analysis of a specific application. Volume IV, Technical Manual, parallels this document, Volume II, but includes details of the individual subroutines with emphasis on the programs of the computer simulation. Volume V, Operations Manual, provides specific instructions on the operation of the simulation, and the auxiliary computer programs used to prepare a new or revised Data Base for the simulation. The reader of Volume V is assumed to have a knowledge of FORTRAN and computer systems. Volume VI, Reference Manual, provides a single place where all the symbols used in the simulation can be found. It will be of value to readers who are concerned with the details of the coding of a subroutine. Volume VII, Data Collection Methods, is a tabulation of the raw data used to make up the 1 January 1961 Data Base. It includes data on the physical characteristics of 117 nations, and notes on the collection methods useful to anyone who wishes to change the Data Base.

This volume is designed to give the reader specific information about the TEMPER model so that he will know what it does, how it does it, and what the results obtained mean. The simulation is divided into four submodels, each of which consists of several subroutines. These subroutines perform activities in one of seven functional areas:

- a. Alliance
- b. Bargaining
- c. Decision Making
- d. Economics
- e. Logistics
- f. Psychological-Political
- g. War

These functional areas are gathered to the four submodels:

- a. Psychological
- b. Economic
- c. War
- d. Decision Making

The organization of this volume is based on these four submodels.

1.0 The TEMPER World

1.1 The Purpose of TEMPER, Its Assumptions, Scope, and Structure

1.1.1 The Basic Purpose, Assumptions and Scope of TEMPER

The purpose of the TEMPER model¹ and computer simulation is to provide an analytic tool for the study of global cold war conflict.

The model attempts to account for the interactions of all the nations of the world up to the point of general nuclear war, usually over a period of ten years. The simulation uses data about the resources, behavior, and attitudes of 117 real world nations and converts these to data on up to 39 aggregated TEMPER world nations, called Nation-Groups. The model is based on several basic assumptions about the behavior of nations. Stated briefly these are as follows:

- a. There are two basic kinds of nations, neutral and bloc member, and all nations of a given kind have the same basic behavior structure although differences in emphasis may be very great.
- b. Each bloc member is in one of two blocs (East or West), and to a degree is responsive to bloc goals and problems.
- c. Each nation has goals and ideals, and its perception of the divergence between the actual state of the world and the ideal state is the motivating force which causes it to modify its behavior.
- d. These behavior modifications seek to reduce the divergence between the actual and the ideal in the period ahead.
- e. The real world can be simulated with adequate accuracy by combining the 117 real world nations into 39 TEMPER world Nation-Groups.

¹In this document the word "Model" is used to refer to the basic theory developed to describe the phenomenon being studied in this case, global cold war conflict. "Simulation" is used to refer to a mechanical device set up to permit numerical analysis of the model. In this case, the mechanical device is a general purpose digital computer, and the TEMPER computer program written for it (Words underlined in text appear in Glossary.)

f. A Nation-Group acts with common purpose (a united population) and internal dissention or subversion is not included in the model directly, but may be represented to a limited extent in the design of Nation-Groups.

The computer simulation operates in the following way: the TEMPER world is embodied in up to 39 Nation-Groups.* Each Nation-Group is described by a list of variables which include descriptions of such things as its economic and military resources, its psychology, and its geographic location. These descriptors, called the Data Base, can be thought of as complete description of the TEMPER world, at a given moment in time. (The Data Base currently in use is a reflection of the real world on 1 January 1961.) These data are stored in the computer's memory at the beginning of a run. A series of subroutines² which call upon the Data Base, are then executed in appropriate sequence under the control of an executive routine.

Each subroutine is concerned with a different segment of the world's behavior. For example, the Force Maintenance and Procurement Subroutine, referred to as FORMAP, computes the spending of the military budget for each Nation-Group. To do this for a given Nation-Group, it first calls the information about that Nation-Group's military forces and its military budget from the computer memory. It computes the cost of operating the current forces. If the budget is inadequate, FORMAP computes the reduction in the force which would result from depreciation and returns the revised data to the computer memory. If there is an excess over operating cost, FORMAP computes what additional forces can be procured from a list of desired additional forces, adds them to the current forces, and returns the revised data to the computer memory. Other subroutines evaluate threats, conduct trade, strengthen and

* The quantity 39 comes from the TEMPER world structure of 13 conflict regions, each of which has the three blocs (East, West and neutral) which may be represented.

² For ease of operation, the total computer program is broken into a number of integral segments called subroutines.

weaken neutral alignments and bloc alliances, and simulate limited land and naval conflicts. When each of the subroutines has been executed, the Data Base will be changed, and will then represent the TEMPER world after the passing of one week of simulated time. Twelve such cycles will simulate a quarter year, and forty-eight a full year. Because some real world functions do not occur every week, the corresponding subroutines are not executed at every cycle. For example, FORMAP is operated quarterly. BUDGET, which computes the amount of taxes and the allocation of revenue to each of several areas of the economy is operated annually. In summary, the TEMPER computer simulation is a computer program which describes the world in simplified form and automatically modifies that description, week by week, to reflect the response which each Nation-Group is expected to make in each of several different functional areas. These responses altogether describe the behavior of the Nation-Group.

This volume describes the TEMPER theory and the simulation concept used for numerical analysis in detail. Volume III, Game Handbook, describes how the simulation computer program can be used. However, it can be seen already that, basically, the user learns by observing the changing world which the Data Base describes. His task is to relate the effect he observes with its cause. He does this by establishing initial values for three different kinds of variables which make up the Data Base. First, he can arrange the 117 nations into a maximum of 39 Nation-Groups so as to emphasize a particular area. Secondly, he can adjust the initial data to reflect a specific real world date. Finally, he can modify the characteristics of a Nation-Group; for example, he can increase or decrease willingness to use military forces to achieve goals. By observing the differences in results as he varies these quantities, the user will gain insight into the complex interactions of the real world.

1.1.2 The Structure of the TEMPER World

The basic data describing the real world is organized in terms of 117 nations.³ Obviously, a computer program which stored data on 117 nations, and then operated on it would require a very large memory, and would take a long time to operate. In recognition of these practical considerations, the

³ Details will be found in Volume VII, Data Collection Manual.

Nation Group Assignments

used for

Situation Examples of Volume IV

13 Land Regions		L, LL, #1 WESTERN BLOC NATION GROUPS	L, LL, #2 EASTERN BLOC NATION GROUPS	L, LL, #3 NEUTRAL NATION GROUPS
J=1		<u>ICELND</u>	*	*
J=2		<u>USACAN</u> CANADA (2) UNITED STATES (3)	*	*
J=3		<u>URGER</u> BELGIUM (5) HOLLAND (16) G. F. R. (12) U. K. (22) LUXEMBOURG (15)	G. D. R. (11)	<u>SCNDIA</u> DENMARK (6) NORWAY (17) FINLAND (9) SWEDEN (20) IRELAND (14)
J=4		<u>FRANCE</u> FR. (ICE (10) GREECE (26) ITALY (27) PORTUGAL (29)	<u>POLCHIK</u> BULGARIA (6) CZECHOSLOVAKIA (7) HUNGARY (13) POLAND (18) RUMANIA (19) ALBANIA (24)	<u>ALGRIA</u> AUSTRIA (4) MOROCCO (28) SWITZERLAND (21) SPAIN (10) YUGOSLAVIA (23) TUNASIA (31) ALGERIA (25) LIBYA (62)
J=5		*	<u>RUSSIA</u> USSR (32)	*
J=6		<u>JAPAN</u> JAPAN (33) NEW ZEALAND (7) PHILIPPINES (35) AUSTRALIA (67)	<u>NKOREA</u> NORTH KOREA (34)	<u>SKOREA</u> SOUTH KOREA (36)
J=7		<u>MEXICO</u> MEXICO (45)	<u>CUBA</u> CUBA (18)	<u>PANAMA</u> COSTA RICA (17) HONDURAS (43) DOM. REP. (39) JAMAICA (44) EL SALVADOR (40) NICARAGUA (46) GUATEMALA (41) PANAMA (47) HAITI (42) TRINIDAD (48)
J=8		<u>TAIWAN</u> TAIWAN (51)	<u>C. P. R.</u> CHINA (49)	<u>MACAO</u> MONGOLIA (50)
J=9		<u>ISRAEL</u> ISRAEL (55) TURKEY (60)	*	<u>EGRAJ</u> AFGHANISTAN (52) LEBANON (57) IRAN (53) SAUDIA (58) IRAQ (54) SYRIA (59) JORDAN (56) U. A. R. (61)
J=10		<u>PAKSTN</u> PAKISTAN (65)	*	<u>INDIA</u> CEYLON (63) NEPAL (64) INDIA (64)
J=11		<u>SVETNM</u> LAOS (71) THAILAND (76) SOUTH VIETNAM (75)	<u>NVETNM</u> NORTH VIETNAM (74)	<u>CAMMAY</u> BURMA (68) CAMBODIA (70) CAMBODIA (69) MALAYSIA (72)
J=12		<u>BRAZIL</u> BRAZIL (79)	<u>VENZLA</u> VEN/UELA (86)	<u>SAMRG</u> ARGENTINA (77) ECUADOR (82) BOLIVIA (78) PARAGUAY (81) CHILE (80) PERU (84) COLUMBIA (81) URUGUAY (85)
J=13		<u>SAFR</u> S. AFR	<u>CAFRC</u> RCONGO (107)	<u>CAFRC</u> (68) (93) (98) (103) (109) (114) (69) (94) (99) (104) (110) (115) (90) (95) (100) (105) (111) (116) (91) (96) (101) (106) (112) (117) (92) (97) (102) (108) (113)

* Regions (per others are reference numbers assigned to the real world nations, usually identified by KK in the TEMPER program.)

N. Note: Figures in parentheses are reference numbers assigned to the real world nations, usually identified by KK in the TEMPER program.

Figure 1-1 A Representative Arrangement of the 117 Real World Nations into the 13 Conflict Regions of the TEMPER World

TEMPER world has been reduced to a maximum of 39 Nation-Groups and 13 conflict regions which embody the 117 real world nations. In addition, the oceans of the real world are represented by seven sea conflict regions. Each conflict region may (but need not) have a neutral Nation-Group, a Western bloc Nation-Group, and an Eastern bloc Nation-Group. The user selects the real world nations which are aggregated to form each of the possible 39 Nation-Groups. He may, if he wishes, place only one or two Nation-Groups in a conflict region, or he may leave it blank. Figure 1-1 which also appears in Volume IV, shows an aggregation designed to emphasize Southeast Asian conflict. Note that the designer has given each Nation-Group a descriptive name (of no more than six letters) which will identify it in computer output statements.

A given Nation-Group can only make war within its conflict region, and is only threatened tactically by the other Nation-Groups in its conflict region. However, it can trade outside its conflict region and participate indirectly in conflict by shipping military forces to those Nation-Groups it wishes to support.

Having described the 13 land conflict regions, the player then establishes seven sea conflict regions. He does this by defining which sea conflict regions are contiguous to each other and to the land conflict regions. He also sets the time required for cargo and military forces to be moved from a given conflict region to any other. All cargo and military forces are assumed to move by sea. Logistics subroutines keep account of these moves. Another Subroutine, NAVFYT (Naval Fight) computes the consequences of encounters between the naval and transport units of conflicting Nation-Groups. Figure 1-2 shows the real world divided into the land conflict regions (labeled L.C.R.) listed in Figure 1-1, with the sea conflict regions (S.C.R.) added.

Once the user has selected the constituents of each Nation-Group, most of the clerical work of melding the real world data into TEMPER world data is done for him automatically by a data management system, a set of auxiliary computer programs described in Volume V, Operations Manual. However, he must establish values for variables which describe aspects of the relationship each Nation-Group has with its conflict region and with other Nation-Groups. Details of this process are given in Volume III, Game Handbook, and will not

TEMPER world has been reduced to a maximum of 39 Nation-Groups and 13 conflict regions which embody the 117 real world nations. In addition, the oceans of the real world are represented by seven sea conflict regions. Each conflict region may (but need not) have a neutral Nation-Group, a Western bloc Nation-Group, and an Eastern bloc Nation-Group. The user selects the real world nations which are aggregated to form each of the possible 39 Nation-Groups. He may, if he wishes, place only one or two Nation-Groups in a conflict region, or he may leave it blank. Figure 1-1 which also appears in Volume IV, shows an aggregation designed to emphasize Southeast Asian conflict. Note that the designer has given each Nation-Group a descriptive name (of no more than six letters) which will identify it in computer output statements.

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be repeated here. It is important to understand that the user must establish his map and interaction variables not only to represent the situation he is studying, but also to respond to the detailed requirements of the computer simulation. Otherwise, unrealistic events begin to occur and the simulation of the real world becomes less and less valid with the simulated passage of time.

1.2 Operation of the TEMPER World

In Section 1.1 of this chapter, reference was made to the sequencing of subroutines to simulate the flow of real world time. This is the heart of the operation of the TEMPER world. Figure 1-3 shows in graphic form how the executive portion of the TEMPER computer simulation sequences the subroutines which embody the theory of the TEMPER model. Having entered the initial TEMPER world description (the Data Base) into the computer memory, the sequencing begins at the point labeled "START". The designations in the rectangles are subroutine names. The subroutines of each submodel are linked to a master submodel control subroutine. As indicated by arrows, the subroutines are linked together so that as each completes its function, it initiates the operation of the next subroutine. Each subroutine has special functions associated with its functional area which it performs at the start of a run to initialize many of the Data Base variables which are functions of other data variables recorded in memory before operation of the subroutines. These start-up, or day zero, functions are shown at the top of Figure 1-3. Let us consider first the weekly sequencing starting at the point "Advance Time by One Week".

1.2.1 Psychological Submodel

Assuming simulated time has been advanced to week number one, the executive causes Control Subroutine PSY to operate. PSY is used to sequence the Psychological Submodel subroutines, and does not itself modify the Data Base. It first sets Subroutine THREAT into operation. THREAT computes the amount of political and military threat perceived (felt) by each Nation-Group as a result of the actions of other Nation-Groups. These threats replace the values previously stored in memory and control and is then passed to Subroutine PERCEP (Perception). PERCEP (with the help of a subroutine called XPERCE, which in effect is an extension of PERCEP) examines the past history of relationships, and the present activities of other Nation-Groups, and computes for each Nation-Group a current measure of hostility from the other Nation-Groups of the conflict region. Information about other Nation-Groups used in these computations is delayed and distorted in ways intended to reflect real world information transmission channels and perception.

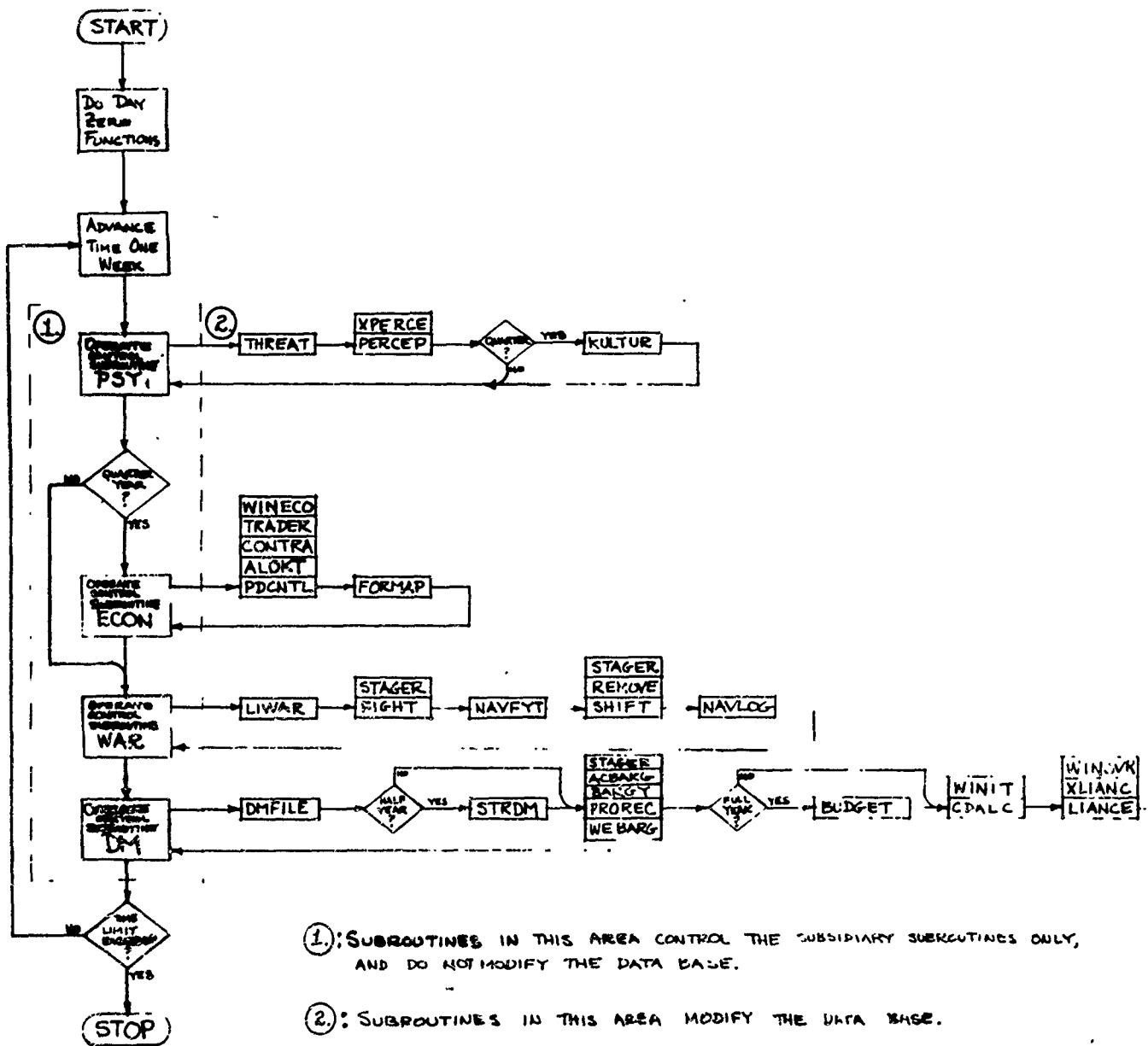


Figure 1-3 Sequencing of the TEMPER Computer Simulation Subroutines

Control is then returned to PSY which checks the week being simulated to see if it is a multiple of twelve. If it is, Subroutine KULTUR⁴ is operated. KULTUR operates on the cultural-ideological descriptors of each Nation-Group once each quarter. The theory of the TEMPER world is that each Nation-Group, if free from threat, would be guided in its actions by five basic factors:

- a. Propensity to use military force
- b. The energy with which it pursues its international goals (external dynamism)
- c. The propensity to invest GNP in capital goods
- d. The propensity to spend for defense
- e. The willingness to impose taxes
- f. Power ratio desires for bloc leaders

KULTUR computes current values for these factors based on the initial values and the threats and hostilities of other Nation-Groups. Control is returned to PSY.

1.2.2 Economic Submodel

If the simulated time is a quarter (i.e., multiple of twelve weeks), control is given to Control Subroutine ECON which controls the sequencing of Subroutine PDCNTL (Production and Control), and Subroutine FORMAP (Forces Maintenance and Procurement), subroutines of the Economic Submodel. PDCNTL computes the current state of the economy for each Nation-Group. It updates GNP, growth rate, work force size, and capital worth. GNP is distributed among six sectors of the economy:

- a. Military
- b. Light industry (durable goods)
- c. Heavy industry (capital goods)
- d. Agriculture
- e. Resources
- f. Services

⁴The diamonds in Figure 1-3 indicate decision nodes; the branch selected in each case depends on the answer to the question asked at the node. It can be seen that some subroutines are operated quarterly, semi-annually, or annually, rather than weekly. In addition, some of the weekly subroutines include functions which only take place at the longer intervals.

Unsatisfied demand is noted for later use by CONTRA-TRADER-WINECO, a group of subroutines operated by PDCNTL. Public and private demand for the products of the economy is computed for PDCNTL by Subroutine ALOKT (Allocation of Demand). When PDCNTL has completed its computations for all Nation-Groups, it causes Subroutine CONTRA (Trade Control) to operate. CONTRA scans the list of Nation-Groups with unsatisfied demand which PDCNTL has just updated and seeks trade opportunities between Nation-Groups. It begins with the Nation-Group with the greatest unsatisfied demand. PDCNTL has established a list of Nation-Groups with which this Nation-Group wishes to trade for political reasons and if a matching inventory can be found, Subroutine TRADER (Political Trade) is used by CONTRA to effect the appropriate adjustments in demand, inventory, and balance of payments. If this process still leaves the demand of the Nation-Group unsatisfied, CONTRA seeks to trade with all its potential suppliers. When CONTRA has completed the trade operations for all of the Nation-Groups with excess demand, it operates Subroutine WINECO (Win Economic Friendship). WINECO reviews the trade just completed and updates the ally and alignment values. When two bloc members trade, their feeling of alliance (ally value) is increased. A neutral Nation-Group feels stronger alignment with its trade partners. These quantities, ally and alignment value, express the degree of friendship felt between two members of a bloc, and between a bloc member and a neutral, respectively. They are very significant quantities which are used by many of the subroutines in the computation of such things as the amount of military aid to be furnished, the priority on the list of potential trade suppliers, and threat. Indeed, these variables express the basic considerations of TEMPER, the changing alliance and alignment of nations in cold war conflict. With the completion of the WINECO functions, ECON transfers control to Subroutine FORMAP (Force Maintenance and Procurement).

FORMAP is used to compute the current status of the military forces of each of the Nation-Groups. PDCNTL has established a military budget. FORMAP first uses this money to maintain existing forces. The cost to operate and maintain (O&M costs) is a function of the number of each type of forces the Nation-Group has in its current inventory. Money in excess of

O&M costs is used to procure additional forces in reponse to the needs of the Nation-Group as computed in Subroutine PROREC (which will be described in Section 1.2.4) during the previous week. If the budget is insufficient to maintain the current military forces, the size of the forces is reduced to reflect depreciation. The functions of the Economic Submodel being complete, the executive transfers control to the control Subroutine WAR.

1.2.3 WAR Submodel

Control Subroutine WAR is the sequencing subroutine for limited war subroutines and the associated logistics operations. It functions on a weekly basis. It begins by operating Subroutine LIWAR (Limited War). LIWAR's basic function is to keep account of the current wars in the TEMPER world. It first scans each of the conflict regions to see if the level of military operations has reached the level of war. If it finds that a war has started during the current week, it assigns it a serial number,⁵ and computes variables having to do with the forces and terrain, used later to compute the progress of the war. If no wars are in progress, control moves to the next subroutine.

Subroutine FIGHT (Fight the Land Battle) follows LIWAR, and computes the results of the current week of fighting for each war. As a function of the terrain type, and size and types of forces engaged, FIGHT computes the losses in men, material and land area for each side, and the appropriate quantities are updated in the Data Base. FIGHT calls on Subroutine STAGER to adjust the Data Base to reflect these losses.

Following FIGHT, WAR shifts to Subroutine NAVFYT (Naval Fighting). NAVFYT considers each current war in turn. For each it notes the number of transport and naval ships each combatant has in each ocean (sea conflict region). This leads to a computation of the probability of encounters between opposing Nation-Groups and the resulting losses of transportation units and naval forces. These results are duly noted in the Data Base.

Having completed the combat subroutines, WAR then initiates the associated logistic activity. Subroutine SHIFT (Shift of Military Forces)

⁵ LIWAR cannot handle more than ten concurrent wars, and stops the run if this number is exceeded.

seeks to optimize the deployment of forces. It first compares needed forces with available forces for each Nation-Group and identifies the Nation-Groups with an excess and those with a need. Starting with the Nation-Group with the greatest need, it seeks Nation-Groups with both a willingness to supply military aid and an excess of forces. Subroutine REMOVE (Force Removal) is used by SHIFT to identify Nation-Groups offering aid to each of the Nation-Groups needing more forces. If transportation is available for redeployment, SHIFT selects the nearest source whose least cost-effective* force will be at the same time the most cost-effective to the recipient. It continues this process until either the need is fully satisfied, all the proffered aid is exhausted, or no more transportation is available. SHIFT repeats the process for the next Nation-Group on the list needing forces and so on, until all possible deployments have been arranged. SHIFT uses Subroutine STAGER to make the necessary changes in the Data Base to reflect these deployments. SHIFT subtracts forces from the shipping Nation-Group when they are being "loaded on the transports", and adds them to the receiving Nation-Group when the transports "arrive".

Finally, WAR causes Subroutine NAVLOG (Naval Logistics) to operate. The function of NAVLOG is to redeploy the naval forces of the world to match the military operations (i.e., land deployments) of the Nation-Groups who own the naval forces. It first updates the Western bloc desired level of operation in each sea conflict region as a function of the contiguous land military operations. It, then, computes the total naval forces deployed in each sea by each of the Western bloc Nation-Groups and identifies the sea in which the deficiency of desired deployment over actual deployment is the greatest. In other words, this is the sea which in the eyes of the Western bloc has the greatest need for additional shipping forces. It then seeks the nearest ocean in which an interested Nation-Group (or Groups) has an excess of forces and shifts these forces to the sea with the largest discrepancy. NAVLOG arranges for the redeployed force to shift its location one sea per week toward the destination sea. The deployments shown in the Data Base in future weeks will reflect this step-by-step redeployment. With its functions now complete, WAR transfers control to Control Subroutine DM.

*Cost-effectiveness is the ratio of cost to operate to counterforce utility both of which are a function of the force type, and the latter of which is also a function of terrain type.

1.2.4 Decision Maker (DM) Submodel

It can be seen that the activities of the three preceding submodels have set the stage for this final submodel which is concerned with military aid and political activities. Control Subroutine DM is used to sequence the subroutines of the submodel and does not affect the variables stored in the Data Base. DM first calls Subroutine DMFILE (Decision Maker Data File) into operation. DMFILE performs the following functions for each Nation-Group:

- a. All alliance and alignment values are decreased slightly to simulate the gradually loosening of ties between two countries if there have been no recent trade relations, or offer of military aid.
- b. Characteristics of strategic weapons are updated to reflect the growth in technology.
- c. The value per unit area of the land of each Nation-Group is recomputed to reflect added capital.
- d. The desire of each Nation-Group for land in its conflict region is computed as a function of present holdings, historic holdings, relative land values, and forces.

As indicated by the decision node, DM calls Subroutine STRDM (Strategic Decision Maker) every half year. STRDM calculates the losses on each side in the event of a nuclear war between the West and East blocs. Because the defender will lose some weapons to the attacker, the loss a bloc sustains depends upon which bloc preempts. Therefore, STRDM computes and stores the losses resulting in preemption by both blocs. Results depend upon such factors as numbers, sizes, accuracies, and vulnerabilities of the strategic weapons.

DM then goes on to Subroutine PROREC (Problem Recognition). PROREC computes the size of the problems each Nation-Group has in connection with each of the other Nation-Groups in the conflict region each week. These problems arise from:

- a. Military operations by others despite threats of retaliation by the Nation-Group.

- b. Threats of retaliation by others to activities of the Nation-Group.
- c. An unsatisfactory ratio of tactical forces.
- d. The discrepancy between land desired and land actually owned.

PROREC then computes for each Nation-Group its perception of the size of the same problems for the other two occupants of the conflict region. The remaining PROREC functions occur only every twelfth week, and are skipped the other eleven weeks. Each Nation-Group identifies the discrepancy between actual and desired defense budget and tax rate, and in addition, the demand in each sector of the economy to be satisfied by trade is established. This demand is used by CONTRA to initiate trade. For only those Nation-Groups with strategic forces, PROREC computes the discrepancies between desired and actual spending for R&D, strategic forces, and tactical forces. Desires for spending reflect the motivations of the Nation-Group and the actions of its bloc leader* and the other bloc leader in these areas. Finally, PROREC computes for each bloc leader the perceived problem that the other bloc leader has in strategic spending. These PROREC functions are extremely important to TEMPER. As mentioned in Section 1.0, TEMPER theory states that nations seek to relieve their problems by rational actions. The simulation uses these problems, together with the cultural motivations, as the driving force behind the actions of each Nation-Group, as will be described in Chapter 5.

After computing the weekly problem for the three Nation-Groups of a conflict region, PROREC calls Subroutine WEBARG (Bargaining Control). WEBARG arranges the problems into an array and then calls Subroutine BARGY (Bargaining Formulation). BARGY performs bargaining between the Western and Eastern Nation-Groups. Basically, it seeks to find common problems and reduce their size through mutual actions. BARGY uses Subroutine ACBARG (Accept Bargains) to implement each bargain which it has tentatively identified. ACBARG will accept immediately bargains which only involve the two Nation-Groups, but the forces of other Nation-Groups

* One owner of strategic forces from each bloc must be designated by the user as the bloc leader. This Nation-Group is assumed to have the strongest voice in setting bloc policy.

may be involved if one Nation-Group plans to effect a reduction in forces by returning forces supplied to it by allies. If ACBARG finds these allies generally are less disposed to use force than the bargaining Nation-Group (i.e., would willingly withdraw), the bargain is accepted. In less clear cases, ACBARG will weight the friendship the bargainer has for each of his allies and the relative sizes of their forces, and will then reach a decision as described in detail in Section 5.6

Since most countries establish government spending on an annual basis, DM operates Subroutine BUDGET (Form the Yearly Budget) once each year. Based on projections of GNP and defense budget, BUDGET computes for each Nation-Group, in order, the new year's defense budget and the amounts for R&D and strategic forces. The balance is used for tactical forces. These funds will be used by FORMAP, as described in Section 1.2.2 to operate existing forces, and if possible to procure new forces.

Subroutine CDALC (Command Allocation) is called each week by DM. CDALC performs two functions: (1) war conduct and termination, and (2) cold war conduct. CDALC first examines each war from the standpoint of both combatants. If both Nation-Groups find that their losses exceed their gains, their military operations levels are set below the level of war, and the war, in effect, is terminated. On the other hand, if either or both sense impending victory, it raises the level of operations, possibly to the point where nuclear escalation becomes possible if either combatant is so equipped. After updating all current wars, CDALC then examines the total weekly problem (computed earlier by PROREC) which each Nation-Group has with each of the other Nation-Groups in its conflict region (excluding the war situations already considered). If the problem rate of change exceeds a threshold, the problem is called a crisis, and CDALC uses Subroutine WINIT (War Initiation and Escalation) to determine the best course of action for the Nation-Group: escalation, de-escalation, or status quo. WINIT considers potential gains or losses, probable results from changes in military operations and deterrent threats. CDALC uses the recommendations from WINIT to compute new values for the level of military operations and deterrent threat. It then repeats these steps for all other Nation-Groups.

As the final step in the weekly cycle, DM calls Subroutine LIANCE (Alliance) into operation. LIANCE first computes the military forces each Nation-Group feels it needs for the changes in military operations and deterrent threat upon which CDALC has decided. When the need is compared with existing forces, it will be found that some Nation-Groups will need help, while others will have excess forces. LIANCE uses Subroutine XLIANC (Extension of LIANCE) to develop for each needy Nation-Group a table of Nation-Groups willing and able to help. The table includes details of the amount, type, location, and owner of the offered forces. This table will be used "next" week by REMOVE to find forces to satisfy the redeployment requests generated by SHIFT. These steps are described in Section 1.2.3 above. LIANCE then uses Subroutine WINOVR (Win Over Through Military Aid) to award ally or alignment points. Each Nation-Group which offers aid is given appropriate points. Figure 1-4 shows graphically the relationship between SHIFT and LIANCE.

Referring to Figure 1-3, it can be seen that the week's activities have been completed. In preparing his game, the game designer has specified the number of real world weeks he wants the simulation to operate (up to a maximum of 480, ten years of TEMPER time). If the EXECUTIVE routine finds that this time limit has not been exceeded, it returns control to PSY and the entire process is repeated. Otherwise, the game is terminated.

1.2.5 Starting Activities

As mentioned in Section 1.2, certain activities are required to prepare the Data Base for operation. Each subroutine sets the values of many variables based on the gamer's inputs. The executive routine recognizes the start of a game as week number zero (also referred to as day zero) and operates the sequencing subroutines in a special order. They, in turn, operate the model subroutines in a special order. A comparison of Figure 1-5, which shows these day zero events, with Figure 1-3 will show the differences. The details need not be considered here; the significant point is that the simulation is designed to automatically compute day zero values for many of the variables from the data furnished by the user. Specific details will be found in the descriptions of the subroutines in the following chapters of this volume.

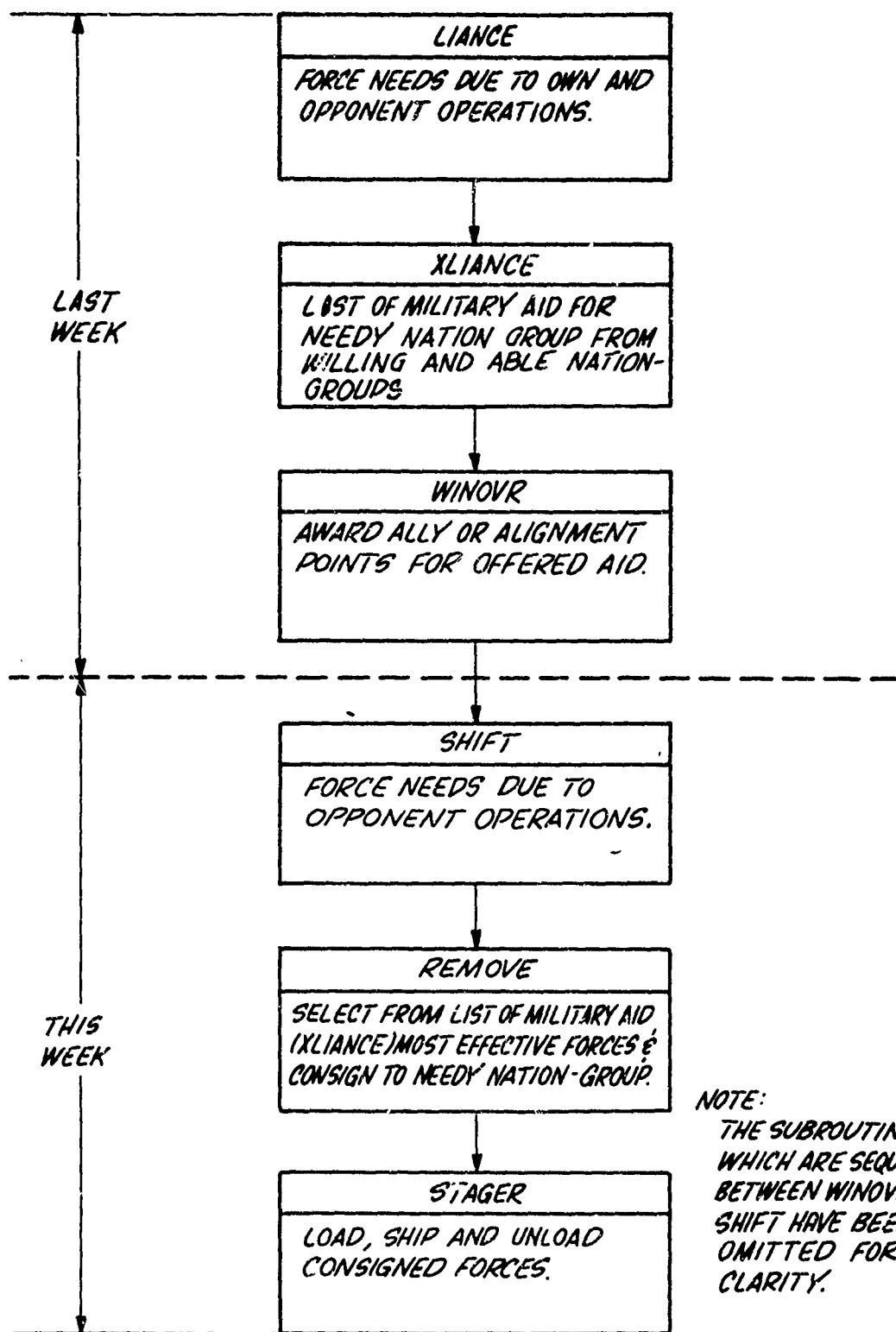
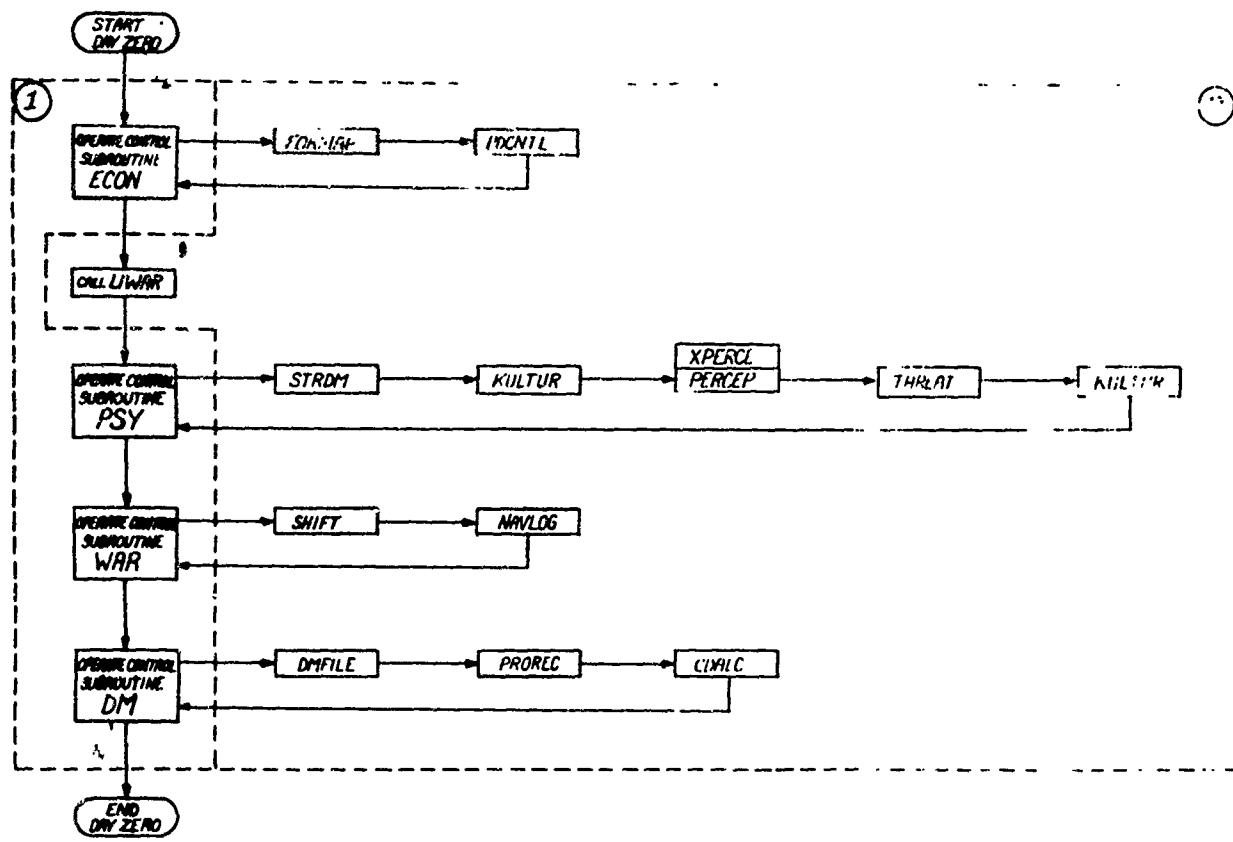


Figure 1-4 Sequence of Events Leading to the Shipment of Military Forces



① CONTROL SUBROUTINES IN THIS AREA SEQUENCE ONLY, AND
DO NOT MODIFY THE DATA BASE.

② SUBROUTINES IN THIS AREA MODIFY THE DATA BASE.

SEE FIGURE 1-3 FOR THE ACTIVITIES OF THE
SIMULATION IN DAY ZERO.

Figure 1-5 Day Zero Activities of the Simulation

1.3 The Theory of TEMPER

From a consideration of the preceding sections, it can now be seen that there are two levels of theory behind the TEMPER simulation. At the first level is the identification of the factors which by themselves can adequately model global cold war conflict and the interactions between these factors. At the second level are the quantities (variables) which describe these factors and the multitude of detailed formulations which specifically relate the variables to one another. The outlines of the first level are found in Sections 1.0 and 1.1 and are implicit in Figure 1-3. The second level is suggested in Section 1.2, but it is clear that there is no way to describe the details of the hundreds of formulations in a way that is both brief and complete. The remaining chapters of this volume contain a detailed and complete description of the functioning of each of the subroutines. Volume IV, Technical Manual, repeats this information with the details of the computer simulation and numerical examples added. It is in these places that the reader will find specific details about each functional area of the model.

2.0 Psychological Submodel

The Psychological Submodel (Figure 2-1) performs those functions that makes TEMPER a dynamic simulation. This submodel is designed to simulate:

- a. Communications channels
- b. Diplomatic channels
- c. Intelligence Networks
- d. "Feelings" that Nation-Groups perceive
- e. National culture and basic national motivations
- f. The threat a Nation-Group feels

Four subroutines (THREAT, PERCEP, XPERCE, KULTUR), perform the necessary operations under the control of a subroutine called PSY.

Briefly the correspondence between the real world and the Psychological Submodel is as follows:

Communications channels in this sense refers to transmitting and receiving information. An assumption made is that various types of information can be collected in different ways and at different rates. In the real world, many channels are available for the flow of information. TEMPER uses a single channel and six selected variables for transmission. These selected variables are perceived by opponents. That is, bias, ambiguity and distortion are simulated. Rates of information flow are considered. For example, status of enemy forces may be available every four weeks while opponent spending on forces may be available every twelve weeks.

Diplomatic channels are related to communications in the sense that information to be used in bargaining is affected by the manner in which it is transmitted.

Intelligence networks are simulated by assuming that overt information is available on a regular basis though accuracy may be questionable. Covert information will be quite accurate when received, but the rate of reception is related to probability of reception. A pseudo-random number sequence is used to simulate the likelihood of receiving covert information. Covert information differs from overt in that the intervals between reception is longer.

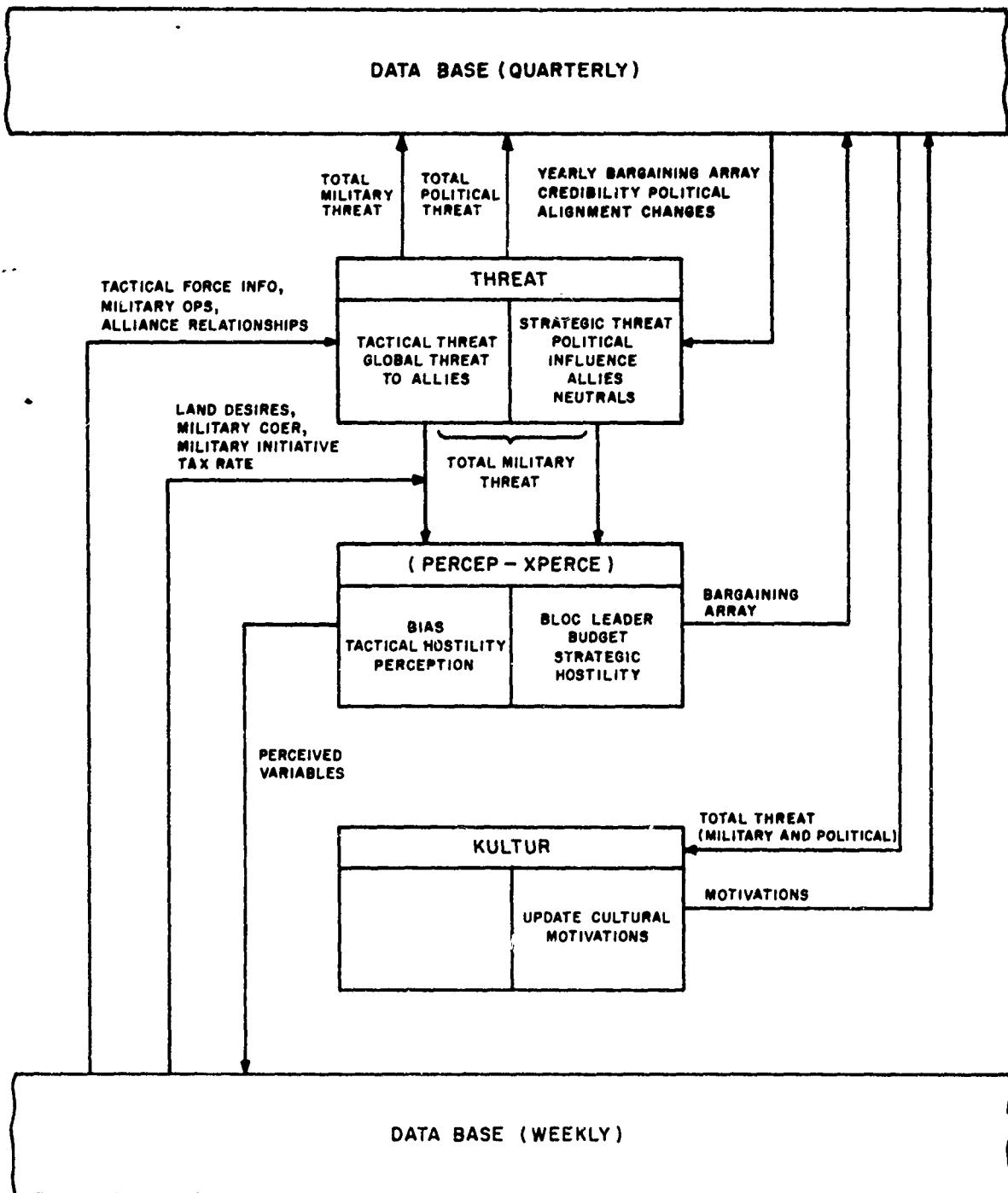


Figure 2-1 The Psychological Submodel

"Feelings" that one Nation-Group has for another are simulated by considering certain types of threat and thus determining hostility. Hostility when related to bias in the perception equation influences the magnitude of perception. Some values are over-estimated. A variable like "verbal-threat", not to be confused with perceived threats, (see glossary) is under-estimated.

National culture is simulated by defining certain types of cultural-ideological factors called motives.

- a. Nation-Group propensity to use force to settle disputes.
- b. The vigor with which a Nation-Group pursues its international goals.
- c. Habits in GNP reinvestment.
- d. Defense spending habits.
- e. Tax rates and their limits.
- f. Desired military power ratios.

Motives are quantified and set into the Data Base at day zero. When a Nation-Group "feels" threatened it adjusts these motives and the resulting motivation results in the ideal world being modified to achieve the best possible compromise between ideal and TEMPER present state. The variance in motivation as a function of threat is set for each Nation-Group at day zero.

Threat to a Nation-Group is of different forms:

- a. Military tactical threat
- b. Military strategic threat
- c. Global Political (to allies) threat
- d. Political influence threat to allies
- e. Political influence threat to neutrals

Another form of threat called "Verbal threat" should not be confused with the above forms. Verbal threat is a form of deterrent threat, i.e., Nation-Group A will indicate to Nation-Group B the level of military operations which, if exceeded by B, will cause A to retaliate.

SUBROUTINES SUMMARY

THREAT updates the five types of perceived threat. Tactical threat and weekly global threat are updated weekly. Military strategic threat and (ally, and neutral) political influence threat are updated quarterly. Total military threat is then computed using tactical and strategic threat. Political threat to East and West bloc members is updated quarterly. Political threat to neutrals is computed differently taking into consideration political threat and military pressure. Neutrals political alignment is modified.

PERCEP distorts selected Data Base information to provide the effect of bias and ambiguity. PERCEP also acts as a communications switchboard and controls rates of covert and overt information and their probability of transmission. It also prepares inputs to the Decision-Maker Submodel and checks to see that no wars are overlooked.

XPERCE receives the "exact" values of certain selected variables from PERCEP and uses a statistical Random Normal Deviate scheme to "perceive" the variable from the eyes of the opponent.

KULTUR determines a Nation-Group's posture from an initial set of motives. Every 12 weeks (quarterly) these motives are updated as a result of threat. The resulting motivations may be weaker or stronger than the original motives with the excursion about the mean being limited by a preset variance. High threat perceived can result in the limit of motivation. Power ratio motivations are used in the Decision-Maker to determine how defense monies will be spent under varying conditions of threat.

Variables that are perceived by the Psychological Submodel are:

- a. Counterforce utility - force strength
- b. Land desired
- c. Level of military operations
- d. "Deterrent" or "verbal" threat
- e. Power ratio - desired military power ratios
- f. Yearly bloc leader bargaining variables.

2.1 Subroutine Threat (THREAT)

2.1.1 General Description of THREAT

The feelings of threat that a Nation-Group perceives from another is simulated by considering military threat and political threat. Five types of threat are aggregated and later provide the motivations which in turn generate dynamic model responses. Under conditions of no threat, the aspirations of Nation-Groups would be static as determined by the values that were originally set into the Data Base by players. Under conditions of total threat the goals of a Nation-Group may be markedly changed. Threat also affects the perception equation in that it (threat) is used to calculate hostility. Since hostility increases with increasing values of threat, a tendency to overestimate (or underestimate) a variable is generated. In addition to determining military and political threat for each nation the THREAT Subroutine updates the political alignment of neutrals and the strategic threat to the bloc. Table 2-1 shows the flow of events in the subroutine.

2.1.2 Detailed Description of THREAT

Various types of "feelings of threat" are computed and are then used to compute hostility and update the cultural motivations. Hostility is used in the perception equation. The motivations are influenced by threat and determine a Nation-Group's basis for goal modification, both short term and long term. The trend of the total government spending and actual defense spending are each individually influenced by threat. Since yearly budget problems are bargainable between bloc leaders, threat provides the basis for bargaining. The five kinds of threat considered are:

- a. Military tactical threat
- b. Military strategic threat
- c. Global political threat to allies
- d. Political influence threat to allies
- e. Political influence threat to neutrals

The first two kinds of threat are used to compute the total military threat. The last three are then calculated in order to update the total political threat variable.

TABLE 2-1
EVENTS IN SUBROUTINE THREAT

1. Each quarter for each ally bloc determine the Bloc Strategic Threat
2. Each week for each Nation-Group accumulate tactical threat
3. Each quarter for each Nation-Group in ally blocs compute strategic threat
4. Each quarter, for each Nation-Group determine quarterly total military threat
5. Each week for each Nation-Group in an ally bloc compute global political threat to allies
6. Each quarter for each Nation-Group in an ally bloc compute ally political influence threat
7. Each quarter compute military pressure to neutrals
8. Each quarter for each neutral update political alignment to eastern and western nations (political threat)
9. Each quarter for each neutral compute political threat to neutrals
10. Each quarter for each Nation-Group in an ally bloc compute neutral political influence threat
11. Each quarter for each Nation-Group in an ally bloc, compute total political threat

Military threat has two components, tactical and strategic. Military tactical threat is computed weekly and occurs among conflict region opponents. It is assumed that disparities in force ratios when influenced by military operations will possibly cause a Nation-Group to feel "uneasy". If a Nation-Group has a favorable force ratio it is assumed that it will feel less threatened for a given opponent's level of military operations (perceived) than if an unfavorable force ratio exists. It is also assumed that the rate of change of feelings of tactical threat is most rapid when a Nation-Group thinks its opponent's level of military operations verges on a state of war. The effect is shown in Figure 2-2.

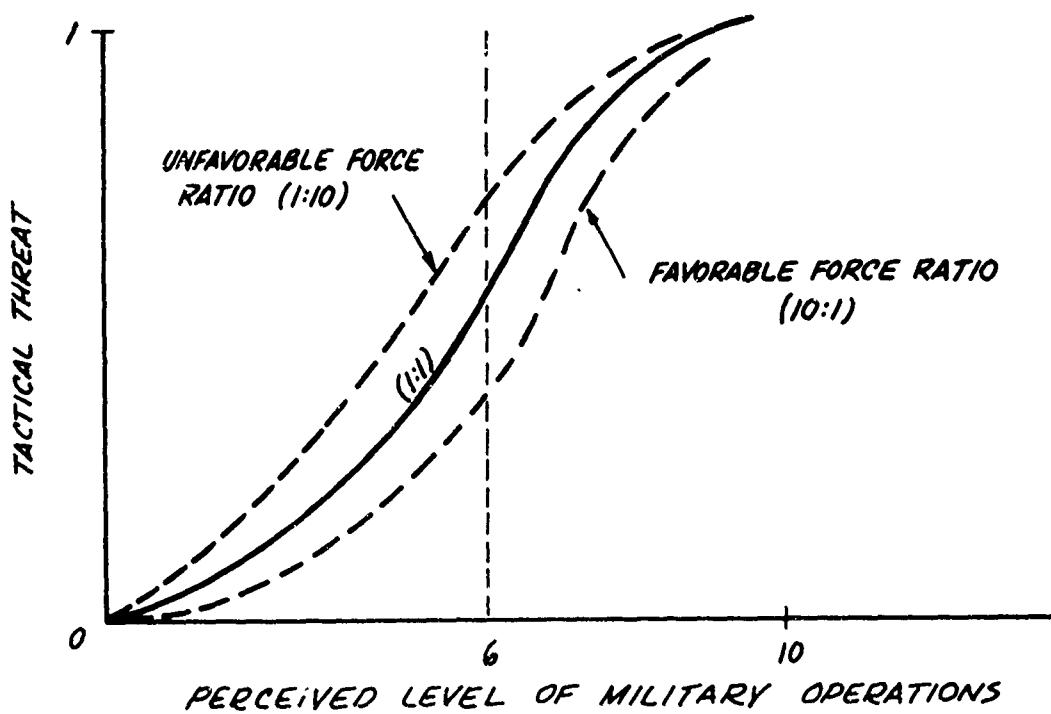


Figure 2-2 Tac Threat vs. Perceived Level of MIL OPS

The curve is an arctangent function weighted and scaled to bound threat between 0 and 1. The equation considers force ratio and perceived level of military operations as its argument. The total military tactical threat to a conflict region member is found by adding the individual threats from the other Nation-Groups in the conflict region, but weighting the major bloc members more heavily, and averaging the weekly values over a quarter.

Tactical threat is used to determine global ally threat; the threat to each of a Nation-Group's allies from their conflict region opponents and thus the threat to the Nation-Group itself due to possible military involvement. It is therefore, the sum of tactical threat to those Nation-Groups who have been given alliance values. This global ally threat is computed weekly and averaged to form quarterly values. An assumption is made that the maximum number of Nation-Groups in a bloc that will feel tactical threat is ten. Tactical threat is also used to compute military pressure to neutrals which will be discussed later.

Military strategic threat is computed quarterly for the major bloc members. The members of a bloc are scanned to find the maximum perceived opponent military operations level. The assumption is made that levels of strategic threat will vary according to what the maximum level of military operation of the opponent is perceived to be. Also considered is the strategic force ratio which in this case is a ratio of expected population loss to opponent bloc versus own bloc due to a simulated nuclear exchange. These elements are combined to form the bloc strategic threat. The curves shown in Figure 2-3 represent bloc strategic threat versus maximum perceived level of military operations of opponent.

Note that if a bloc has a favorable force ratio it will not feel a strategic threat until it perceives an opponent military operations level of 8, which approaches the nuclear war level. The slope of the curve is very steep here. Note also that an unfavorable strategic force ratio results in a bloc feeling threatened at a much lower perceived military operations level. Once bloc strategic threat is determined, Nation-Group strategic threat is computed by applying Nation-Group credibility, i.e. a measure of past military history of retaliation. Equations 1), 2), and 3) show the calculations that take place.

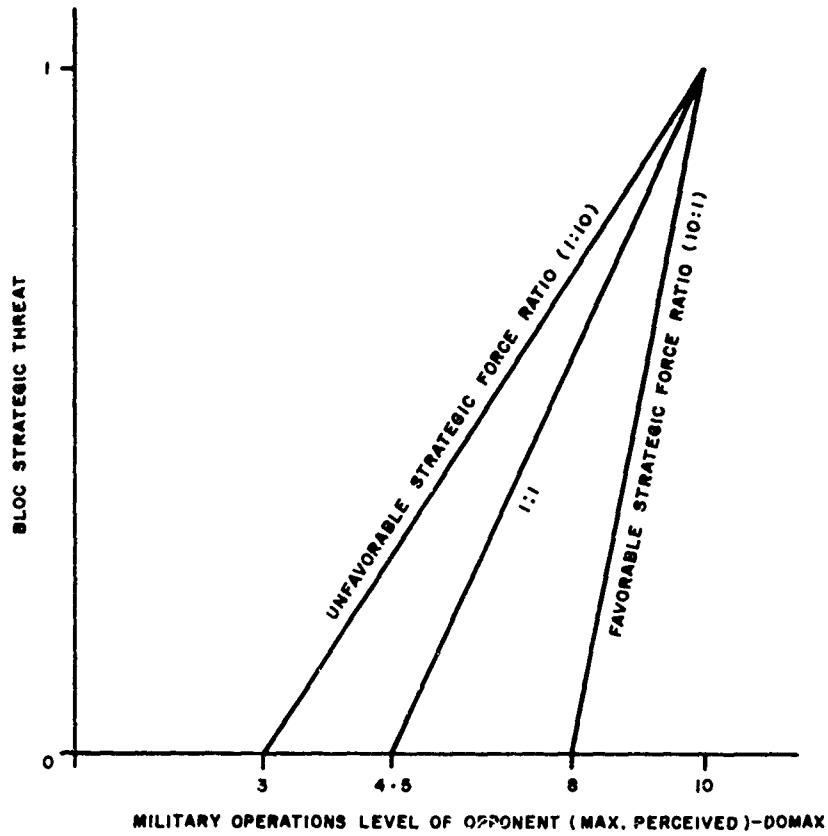


Figure 2-3 Bloc Strategic Threat Versus Military Operations Level of Opponent (Max. Perceived)- Domax

Total military threat is calculated quarterly by adding military tactical threat to military strategic threat, but weighting tactical threat twice as much to represent the immediacy of tactical threat. See Equation 3. This threat, along with total political threat is used in Subroutine KULTUR to compute the quarterly motivations.

For non-neutrals (i.e., bloc allies) political threat has three components: global threat to allies, political influence threat from allies, and political influence threat from neutral.

Global threat to allies is computed by first scanning the list of allies. Not all members of the bloc are necessarily allies. The ally values may range from 0 to 1. Alliance is directional (i.e., there is a value assigned from Nation-Group "A" to "B", representing the value "A" attaches to the alliance with "B", and another from "B" to "A"). To compute the global threat to allies, the value assigned (by "A") to the alliance (with "B") is used to weight the ally's ("B's") contribution to ("A's" feeling of) global threat. If the alliance value is 0 (if the Nation-Group examined is not assigned any value), no global threat to allies is accrued. If the alliance has a value, however, an increment of threat may be accrued. The amount of this increment is computed each week and is a function of both the value of the alliance and the amount of tactical threat that the ally feels from both the opponent (other bloc member) and the neutral in its conflict region. The value is modified to reflect an average threat from all (n) allies and to effect an averaging of the value for the quarter.

This threat component reflects the threat felt by a Nation-Group when its allies become involved in a local war. It is considered a part of the political threat since it is tied closely to the alliance and the possibility of conflict is one of the costs of alliance. Assume a single ally was valued at 1.0 and the ally had a maximum threat from the other bloc member and the neutral in that conflict region (1.0 from each) for the full quarter. The quarterly contribution of that ally to the global threat to allies would be 0.20. (See maximum contribution from one ally in Figure 2-3.) If the ally had no contiguous neutral then the maximum quarterly contribution from that ally would be 0.10.

Figure 2-4 shows how the threat may be accumulated over the quarter. The curve for maximum contribution by any ally assumes that the ally value is maximum, that there is a neutral and other bloc member in the ally's conflict region, and that the tactical threat to the ally is maximum for both cases. The maximum accumulation by the week from all allies assumes that the nation has ten allies (i.e., $n = 10$) each making the maximum contribution. The curve levels off as a result of the bounding of maximum value to 0.5.

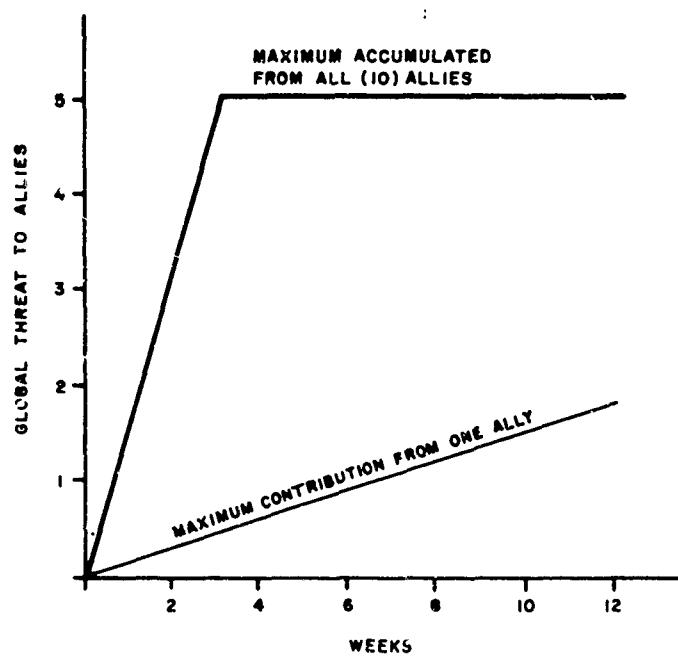


Figure 2-4 Maximum Values for Accumulated Global Threat

Political influence threat from allies is a function of both the alliance value assigned by the ally in question and the amount of alliance change per quarter. Only the contribution from allies who have reduced their award of value to the alliance are considered so that the strengthening of the alliance with other nations does not act to weaken this threat.

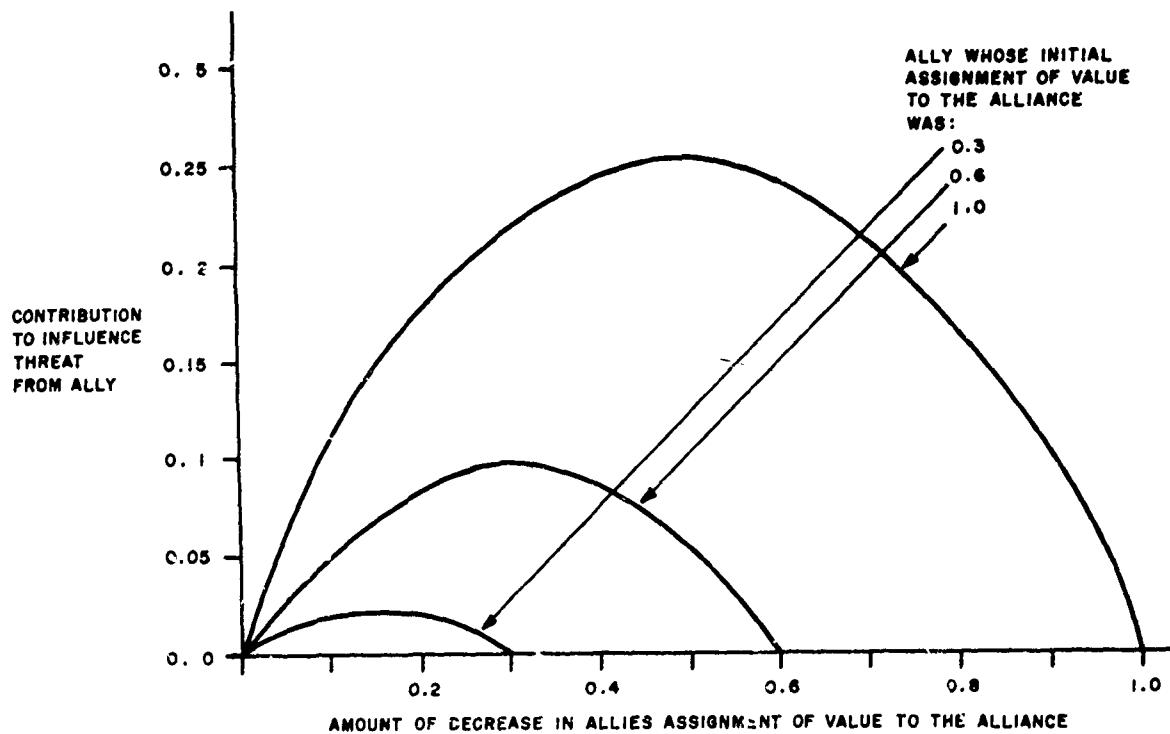


Figure 2-5 Amount of Decrease in Allies Assignment of Value to the Alliance Versus Contribution to Influence Threat from Allies

An ally's contribution to influence threat is a function of the end of quarter value placed on the alliance by the ally, and the amount of decrease, from the beginning of the quarter, in that value. Only change resulting in help offered to the ally (or denied him) is used. The normal decay of the alliance growing from no need for the alliance is not used in their computation. If the net decay, from alliance needs and the associated granting or denial of help, is .3 and at the start of the quarter the value of the alliance had been .6 then the current value would be .3 (not counting the normal decay rate). The contribution to influence threat would be .09. If at the beginning of the quarter the alliance value had been 1.0 the new value would be .7 and the contribution to influence threat would be .21. A maximum threat results when the ally withdraws half the value. Beyond this point the contribution to influence threat is less even though the withdrawal is higher. In theory this represents the core where it is felt that the alliance has

decayed too much and it is not as possible to mend the relationship. Therefore the importance is discounted to allow focus on the more possible retrieval of better relationships in cases where the degradation is not so great. Equation 5 shows the formulation of the value. It is accumulated for all allies. The total amount may not exceed 1/3 for any quarter.

The total value for political influence threat from allies is bounded so as not to exceed a value of 1/3 in any single quarter.

The political alignment of a neutral is influenced by military pressure. If a neutral senses that there is a high likelihood of being attacked by a bloc member, then the neutral may assign some additional political alignment to that bloc member in its conflict region. To determine whether or not to calculate a change in alignment, a check is made to see if there is a high, combined unsatisfied-desire-for-land and tactical threat from the bloc in question. If so the force ratios are checked. If the neutral is inferior by a ratio of 1:3, then there is presumed to be high military pressure, because both motive and capability to attack the neutral are present. Under these circumstances the political alignment of the neutral is increased toward the threatening bloc, thus simulating an attempt to appear more friendly and less provocative.

The calculation of the amount of shift is based on the existing degree of alignment and is shown in Figure 2-6. Also see Equation 6 in the list of equations, Section 2. 1. 3.

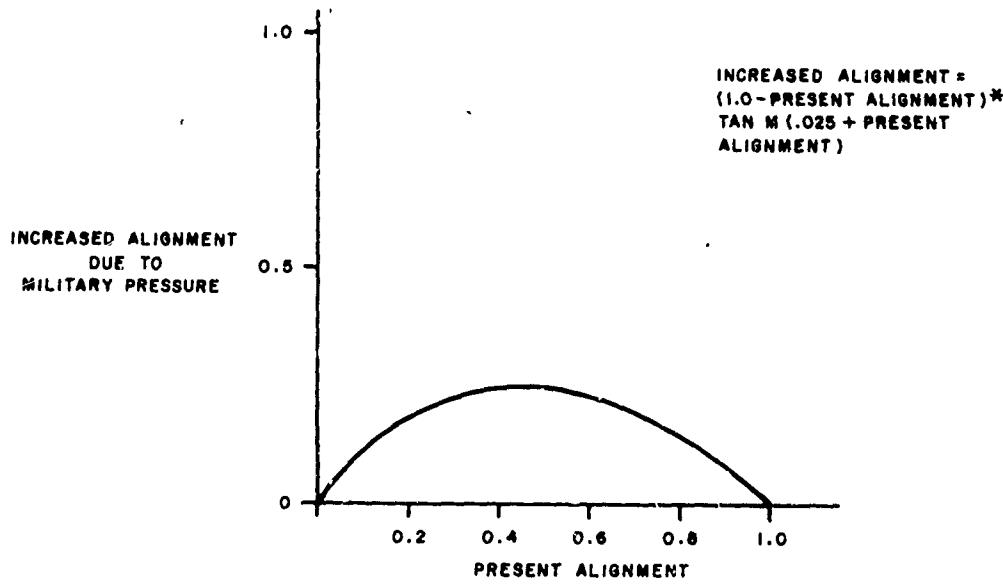


Figure 2-6 Present Alignment Versus Increased Alignment Due to Military Pressure

Quarterly political pressure to neutrals may cause the neutral to decrease its alignment. First, it is determined whether more alignment exists than the degree of independence of the neutral will allow. The amount of unassigned alignment is compared with the degree of independence. If the unassigned amount is less than the degree of independence, then the current alignment value is decreased as a function of the excess alignment.

Figure 2-7 shows how much alignment will be taken away based on the excess alignment that exists. Also see Equation 7.

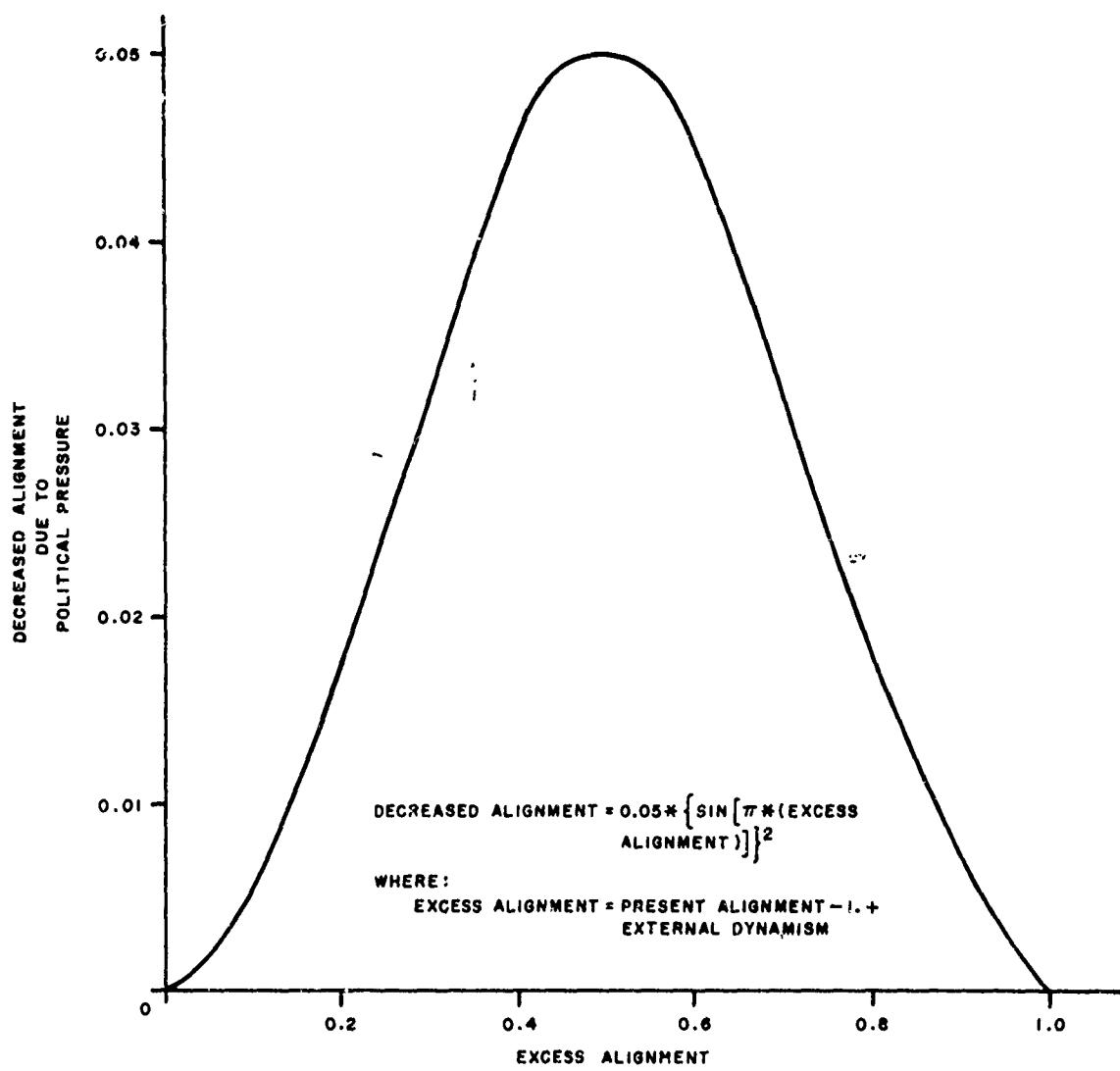


Figure 2-7 Excess Alignment Versus Decreased Alignment Due to Political Pressure

Political influence threat from neutrals is sensed by both Eastern and Western allied nations. The process is exactly that described for political influence threat from allies, except that the degree of political alignment and its change are used instead of the value of the alliance and its change. The level of threat felt from this source by a nation may not exceed a value of 1/6.

Total political threat felt by a nation is a function of three previously described types of threat:

	<u>Upper Bounds</u>
Global Threat to Allies	(1/2)
Political Influence Threat from Allies	(1/3)
Political Influence Threat from Neutral	<u>(1/6)</u>
Max possible total	1. 0

While it is accumulated weekly it is used each quarter after all weekly and quarterly components have been accumulated.

As was the case with total military threat, political threat is used in computing the motivations in Subroutine KULTUR. It is, therefore, changing motivations which are so pervasive in the model and cause the model results to be dynamic. See Equation 8 for the computation of total political threat for members of East and West blocs.

Quarterly political threat to neutrals is computed on a basis different than that used for allied bloc members. It is computed in a fashion similar to political pressure to neutrals. The assignment of political alignment points is compared to the degree of independence of the nation, and the excess assignment of alignment points is taken as political threat to a neutral. The computation of excess alignment is shown in Equation 7a. This value is used for a neutral as the political threat component in setting motivation, instead of the sum of other kinds of threat.

2. 1. 3 Equations in THREAT

(1) MILITARY TACTICAL THREAT

$$\text{MIL TAC THRT} = 0.5 + \frac{1}{2.5} \arctan \left[\frac{(\text{Milops perc. - } \frac{\text{Own Forces}}{\text{Perc. Opponent's Forces}} - 5.)/2)}{\text{ }} \right]$$

Note: The force ratio is bounded between 0. and 1. If opponent perceived force is zero, the computation is not made.

(2) MILITARY STRATEGIC THREAT

a. Strategic force ratio_{attacker} = $\frac{\text{Population loss}_{\text{defender}}}{\text{Population loss}_{\text{attacker}}}$

If Strat force ratio < 1; expected Str. Damage = $4.5 - (1.5 \times \text{Str force ratio})$

If Strat force ratio > 1; expected Str. Damage = $8 - (3.5 \times \text{Str force ratio})$

b. Bloc Strategic threat =
$$\frac{\left(\frac{\text{Max Milops perc} - \text{Exp Str Damage}}{10 - \text{Exp Str Damage}} \right)}{\left(\text{Population Loss}_{\text{Defender}} \right)}$$

c. Nation-Group Str Thrt = (Bloc Strat Thrt) (Nation-Group Credibility)

(3) TOTAL MIL THREAT

$$\text{Total MIL Thrt} = (2/3 \text{ tactical threat} + 1/3 \text{ Nation-Group Str Threat})$$

Note: Neutrals possess no strategic forces, thus $\text{MIL Thrt}_{\text{total}} = \text{TACT THRT}$

for all allies

(4) Weekly Global Threat = $\sum_{\text{to Allies}} \left(\text{Value of } \left(\begin{array}{l} \text{Tac. Threat to Ally from Opponent} \\ \text{Alliance} \end{array} \right) \right) \left(\begin{array}{l} \text{N-G and neutral in conflict region} \end{array} \right)$

Note: May not exceed a value of 1/2

$$(5) \text{ Quarterly Political Influence} = \text{Sum for } \begin{bmatrix} \text{Threat from Allies} \\ \text{all allies} \end{bmatrix} \begin{bmatrix} (\text{present alliance value}) \times \\ (\text{amount of decrease}) \\ (\text{in value}) \end{bmatrix}$$

Note: The value must be positive and between 0 and 1/3.
Negative values are set to zero.

$$(6) \text{ INCREASE IN } \underline{\text{POLITICAL ALIGNMENT}} = (1 - \text{Present alignment}) \times \text{hyperbolic tangent} \\ \text{of } (0.025 + \text{Present Alignment})$$

(7)

a. Excess = (Political Alignment - 1 + External Dynamism)

Note: This value must be positive. Decreases are not made.

b. Decrease in alignment = $0.05 \times \sin^2(\pi \times \text{Excess})$

$$(8) \text{ Total Political Threat} = \text{Global threat to allies } (< 0.5) + \text{political influence} \\ \text{threat from allies } (< 0.33) + \text{political influence} \\ \text{threat from neutrals } (\leq 0.17).$$

2.2 Subroutine Perception (PERCEP)

2.2.1 General Description of PERCEP

The accuracy with which Nation-Groups perceive the state of opponent Nation-Groups is governed by the PERCEP Subroutine which in turn relies on the XPERCE Subroutine in the TEMPER model. In theory, distortion of the available data is partly a function of data bias which represents the "hardness"** of the variable. Motives, for example, are soft variables and are likely to be more distorted than size of force. This phenomena is magnified under conditions of greater hostility. Distortion is a function of information about change. Both the nature of the variable being perceived and the openness of the society (freedom of travel, degree of reporting in open literature, criticism permitted) being perceived have an effect on the distortion. In the TEMPER world information on the softer variables is less likely to be available for perception. Open societies are less likely to obtain information about closed societies than vice versa. There is likely to be greater deviation in data received from open sources than from covert (intelligence) sources. Covert sources, although erratic in delivery of information, are more likely to be accepted than open sources. Table 2-2 shows the sequence of events in PERCEP.

TABLE 2-2

SEQUENCE OF EVENTS IN PERCEPTION SUBROUTINE

PERCEP

1. Compute static component of bias for all six perceivable variables.
2. Compute hostility between bloc leaders on the basis of comparative political alignment gains and strategic threat.
3. Call XPERCE to set perceived bargaining array (budget spending values) and perceived values for bloc leaders.
4. Call XPERCE to set perceived military power ratio motivation for bloc leaders.
5. Compute weekly tactical hostility between nations on the basis of perceived desired land, military motivation, and tactical threat.
6. Call XPERCE to set perceived: counterforce utility; desired land; military operations; verbal (deterrent) threat.
7. If war exists, check to see that nations have not failed to perceive it. If they fail to perceive an attack, PERCEP sets the nations level of military operations to a war level.

**A hard variable is one where the quality is clearly definable and the quantity precisely measureable.

2. 2. 2 Detailed Description of PERCEP

On day zero the static bias for each variable to be perceived is computed. This is then used as a constant in computing the perceived value of each variable. Hostility between bloc leaders is computed on the basis of the ratio of the changes to political alignment and the strategic threat, and later used in determining how much to distort the bargaining arrays (i. e., the opponents budget spending for use in bargaining). The power motivation ratio perception for bloc leaders uses the same hostility factor. A new hostility factor is computed on the basis of tactical factors and used to perceive counterforce utility, desired land, military operation, and verbal threat for opponents in a conflict region.

The function of distorting the information takes place in the XPERCE Subroutine. The other functions described above take place in PERCEP.

On day zero, only, a static bias is computed for each of the six variables to be perceived. These six variables are:

<u>Definition</u>	<u>Subroutine of Origin</u>
a. Quarterly* Government expenditure and Military Research, Strategic and Tactical expenditure.	PDCNTL- FORMAP
Power ratio motivation	KULTUR
CFU of military forces	LIWAR
Desired land	DMFILE
Military operations	CDALC
Verbal threat	CDALC

*For bloc leaders only.

This calculation takes the "hardness" of the data into consideration; that is, the degree to which it may be accurately measured even when perfect information is available. Table 2-3 shows how this bias is set for each variable. Note that the negative exponent for the verbal threat computation has the effect of underestimating the threat, whereas, all other perceived variables have bias of greater than 1. See Equations, Formula 1, Section 2.2.3.

TABLE 2-3
PERCEP FUNCTION ONE--STATIC BIAS

Fortran Name	Identifier	Ambiguity (AMB)	Expectation Class(EXPT)	$\frac{1+AMB}{100}$ Class
(Bargaining Array)	1	1.	+1.	1.01
(Power Ratio Motivation)	2	3.	+1.	1.03
(Counterforce Utility)	3	1.	+1.	1.01
(Desired Land)	4	3.	+1.	1.03
(Military Operations Level)	5	2.	+1.	1.02
(Verbal Threat)	6	3.	-1.	0.97

Hostility between bloc leaders is computed on the basis of their status in the cold war and their strategic security. In order to compare status in the cold war, a bloc leader determines the ratio of increases in alignment awarded to his opponent and to himself. This ratio, if above one, will indicate the cold war is going badly, while a value less than one indicates it is going well. The ratio is multiplied by the value for the bloc strategic threat felt (which represents strategic security) to obtain a hostility rating. Thus, the hostility will be lower than the bloc strategic threat if the cold war goes well, but be a magnification of the strategic threat if not. Note that only positive values of alignment gain are used. Losses are seen as no gain.

This hostility factor is used both in the perception of the bargaining array and in the perception of power ratio motivation which are computed between bloc leaders. See Equation 2 in the list of equations, Section 2.2.3.

XPERCE is called first to perceive the bargaining array and perceived values for the bloc leaders, then to perceive the military power ratio motivation.

Tactical hostility between all nations is used in determining the perceived values for counterforce utility, desired land, level of military operations, and verbal (deterrent) threat. The calculation has three components which are combined. These components are:

- a. Perceived opponent desire for land.
- b. Military motivation of opponent.
- c. Tactical threat.

After appropriate weighting to keep the values on scale, the desire for land is multiplied by a factor representing a militaristic capacity (see Equation 3). This aggregation of provocative "greed" and military inclination to do battle may make up three-fifths of the value of tactical hostility if the other component, tactical threat, is also present at maximum strength. See Equation 3 in the list of equations.

XPERCE is called to perceive: counterforce utility; desired land; military operations; and verbal (deterrent) threat. After distortions are made, a war check is initiated. There are two kinds of war which assume importance in TEMPER; Conventional War (because it represents a transition from cold war to hot war) and Nuclear Exchange. These are represented by the level of a variable which measures the level of military operations. PERCEP checks to see if through misperception a nation has overlooked the fact that it is in one of these kinds of war. If so, the variable is reset to the threshold level of the kind of war involved, so that the nation will recognize it.

2.2.3 Equations in PERCEP

1.
$$\text{Bias} = \left(1 + \frac{\text{ambiguity}}{100}\right)^{\text{Expectation Class}}$$

Where the ambiguity is 1, 2, or 3, depending on the variable to be perceived. The expectation class is + or - 1, depending on whether it is expected that the variable would be over or underestimated.

2.
$$\text{Hostility} = (\text{Opponent gains in alignment}/\text{Own gain in alignment})(\text{Bloc Strategic Threat})$$
 Only positive values of alignment gain are used.

3.
$$\text{Tactical hostility} = \left(\frac{\text{Perceived desire for land}}{4}\right) \times \text{military capacity} + 5 \text{ (Tactical Threat)}$$

Where Military capacity = (Military coercion motivation) + (defense spending motivation) + 10 (tax motivation) + 5 (Tactical Threat).

2. 3 Subroutine Perception-Extension (XPERCE)

2. 3. 1 General Description of XPERCE

XPERCE is a subroutine which when called distorts data. In performing this function it checks to see if it is time to receive any new information on the variable being perceived. If so, the type of information is checked (overt or covert) and for covert determines on the basis of the probability of detection if the data was actually perceived. In theory, overt information will flow at a constant rate depending on the variable. In the TEMPER world a variable has some standard deviation from a mean (real) value. It is assumed that covert (intelligence) data will not be fully accepted and will be averaged with the previously perceived data. Overt data will be accepted on face value. If both types are received, the overt will be assumed to be correct. Table 2-4 shows the order of events in XPERCE.

TABLE 2-4

XPERCE

- a. Determine whether new information has been received for perception.
- b. Compute the perception of the variable.
- c. Update or modify the data on the variable on the basis of the kind of new information.

2. 3. 2 Detailed Description of XPERCE

If it is day zero, perceived values are set to equal the real values for variables to be perceived. On other occasions when XPERCE is called, it performs three main functions; first a determination as to whether or not new information has been received for perception, computation of perceived value, and modification of old information on the basis of the new information.

New information may only be transmitted at particular frequencies depending on the nature of the variable, and the kind of information (overt or covert). Overt information will be available more often than covert information, and the latter (intelligence) is less of a steady stream and a function of

how open the society is. There will be a greater probability of intelligence data being collected at the scheduled times from the Western bloc than from the Eastern bloc. TEMPER uses both of these concepts in determining whether or not a perceived variable will have new information available to be perceived.

Table 2-5 shows the information transmission rates for the perceived variables. For each variable sent to the XPERCE Subroutine, it is determined whether the week is a multiple of the data rate. If so, then the variable is further examined. If it is overt information, then the new information is acted upon by the perception function to establish the new perceived value. (In fact, the variable may not have changed, but the perception of it is recomputed.)

TABLE 2-5
INFORMATION TRANSMISSION RATES

<u>Opponent Variable Name</u>	<u>Covert Data Rate (weeks)</u>	<u>Overt Data Rate (weeks)</u>
Bargaining array	24	12
Power Ratio Motivation	12	4
Counterforce Utility	12	4
Desired Land	12	4
Military Operations Level	2	1
Verbal (deterrent) Threat	2	1

If the information is covert, there is a check made to see whether or not the probability of transmission allows the variable to be examined. An evenly distributed random number is generated. If it is lower than the value in the probability of transmission (Table 2-6), then the variable is to be perceived on the basis of the new information.

TABLE 2-6
PROBABILITY OF TRANSMISSION OF EVALUATED DATA
TO PERCEIVER FROM OPPONENT

PSTRAN (IAMB, ND)

Ambiguity of Variable	WE	EN	NW	WN	EW	NE
1. Bargaining Array	0.5	0.8	0.9	0.8	0.7	0.6
2. Military Operations Level	0.3	0.7	0.8	0.7	0.5	0.5
3. Power Ratio Motivation						
Desired Land	0.3	0.5	0.6	0.5	0.4	0.4
Verbal Threat						

The perceived value of a variable is computed if it passes the above tests on the availability of information. This computation has two elements, the static bias element, and the "stability" of the value. (See Equation 1.)

Static Bias was computed on day zero in the Subroutine PERCEP. The bias is magnified by the degree of hostility that the perceiver feels toward the nation whose variable is to be perceived. Different strategic or tactical hostility figures are used from PERCEP, depending on the variable being perceived. Table 2-7 shows how the static bias is magnified. (See Equation 1, Section 2.3.3.)

This magnified bias is further modified as a function of the stability of the variable. If there is a large variance in the variable (its value often changes over a wide range), there may be substantial modification of the bias-hostility factor. If the deviation of values is small, there may be only modest modification of the bias-hostility factor. The modified factor is multiplied by the new information on the variable (the true setting for the variable). Table 2-8 shows the standard deviation used for both overt and covert information. The table for overt (open) information has more deviation (and therefore more distortion) reflected.

TABLE 2-7
BIASES INTRODUCED DUE TO VARYING DEGREES OF HOSTILITY

Static Bias	Hostility Level									
	1	2	3	4	5	6	7	8	9	10
1 (Bargaining Array) bias = 1. 01	1. 01	1. 02	1. 03	1. 04	1. 05	1. 06	1. 07	1. 08	1. 09	1. 10
2 (Power Ratio Motivation) bias = 1. 03	1. 03	1. 06	1. 09	1. 13	1. 16	1. 19	1. 23	1. 27	1. 30	1. 34
3 (Military Force Value) bias = 1. 01	1. 01	1. 02	1. 03	1. 04	1. 05	1. 06	1. 07	1. 08	1. 09	1. 10
4 Desired Land bias = 1. 03	1. 03	1. 06	1. 09	1. 13	1. 16	1. 19	1. 23	1. 27	1. 30	1. 34
5 (Military Operations Level) bias = 1. 02	1. 02	1. 04	1. 06	1. 08	1. 10	1. 13	1. 15	1. 17	1. 19	1. 22
6 (Verbal Threat) bias=0. 97	0. 97	0. 94	0. 91	0. 89	0. 86	0. 83	0. 81	0. 78	0. 76	0. 74

TABLE 2-8

Overt Standard Deviation

Ambiguity Class	WE	EN	NW	WN	EW	NE
1	0.02	0.02	0.04	0.03	0.03	0.03
2	0.04	0.02	0.05	0.04	0.04	0.03
3	0.06	0.03	0.05	0.05	0.06	0.04

Covert Standard Deviation

Ambiguity Class	WE	EN	NW	WN	EW	NE
1	0.02	0.01	0.03	0.02	0.02	0.02
2	0.03	0.01	0.04	0.03	0.02	0.02
3	0.04	0.02	0.04	0.04	0.04	0.03

Updating the perceived value is performed differently for changes resulting from overt information and covert information. Covert information from reliable sources is more credible than that received through open sources. Therefore, the perceived value resulting from covert information is accepted and it replaces the old perceived value. If the new perceived value results from overt or open information, it is not so readily accepted. In this case, the new perceived value is averaged with the old perceived value and the average is accepted. Where both kinds of information are available, then the covert data is accepted and the open information is ignored.

2.3.3 Equations in XPERCE

$$1. \quad V_{N_i} = (B^H + \sigma R) V_{P_i}$$

where

V_{N_i} = new perceived value for variable i

B = static bias

H = hostility between perceiver and perceived

σ = standard deviation of data received

R = normally distributed random number

V_{P_i} = previous perceived value for variable i

2.4 Subroutine KULTUR

2.4.1 General Description of KULTUR

There are certain roughly quantifiable cultural-ideological factors called motives which are different for different Nation-Groups. These motives include:

- a. Government propensity to use force to settle international disputes
- b. The energy with which a nation pursues its international goals
- c. Propensity to reinvest GNP in capital goods.
- d. Propensity to engage in defense spending.
- e. Propensity to channel money into taxes.
- f. Desired military power ratio.

These are cultural motives. In the absence of threat, a Nation-Group will be bound by these motives in its courses of action.

Under increasing levels of threat, however, all countries will tend toward a common posture - i.e., strong internal government controls, "guns instead of butter", etc. The common posture is set in TEMPER as a limit. Each area of behavior in TEMPER (defense spending, propensity to tax, etc.) has its own value. The tendency to move from the basic or static motive toward the limit may be called a motivation. Motivation is generated each quarter as a function of the felt threat.

KULTUR is the subroutine which determines, from the basic set of motives modified by the external threat level, the levels of the cultural motivations, and thus, the resulting behavior of the Nation-Group.

Table 2-9 shows the order of events in the KULTUR Subroutines.

TABLE 2-9
EVENTS IN KULTUR SUBROUTINE

- a. Compute combined political military threat
- b. Compute* cultural base (Static Motives)
- c. Compute external dynamism
- d. Compute motivations for all motives except external dynamism and desired military power ratio
- e. Compute desired military power ratio

2.4.2 Detailed Description of KULTUR

In KULTUR, the motivations subroutine, cultural motives are formed for each Nation-Group. These motives represent the objectives which guide and constrain the behavior of each Nation-Group in the absence of threat. Cultural motives are set to indicate national behavior regarding the use of military coercion, reinvestment in capital goods, defense outlay, government spending, independence, and the force or military power ratio which it wishes to maintain with its conflict region opponents. These motives are set as motivation array for each Nation-Group.

The KULTUR Subroutine establishes each static motive on the basis of input motivations and perceived threat at day zero. These initialized values then become the permanent static motives of the Nation-Group, or the levels toward which each of these values would tend in the absence of threat. Motivations are determined each quarter. Under no threat a Nation-Group will assume its static motive for the motivation. Under threat the motivation will tend toward a limit common for all nations. The following motivations are set in KULTUR:

- a. External dynamism
- b. Internal initiative
- c. Military coercion
- d. Military initiative
- e. Tax rate motivation
- f. Military power ratio

*Day zero only

Which motives are changed and the extent and direction of change depend on the type of threat, the allowable amount of change for the motive, and the extent to which the different kinds of threat will affect them.

The KULTUR Subroutine is called twice for day zero operations. The first time is to compute the military power ratio motivation for use in perception which is later used to compute threats. Later, using the computed threats, KULTUR sets the initial values for the static motives, and on the basis of these and threat, computes values for the motivations.

The combined political-military threat is a weighted average of the total military threat and total political threat, both computed in Subroutine THREAT. The formula (see Equation 1) weights the function 2:1 in favor of military threat, since it appears to be more immediate. Figure 2-8 shows how values for the combined threat might vary under conditions where military threat increases, assuming different values for political threat.

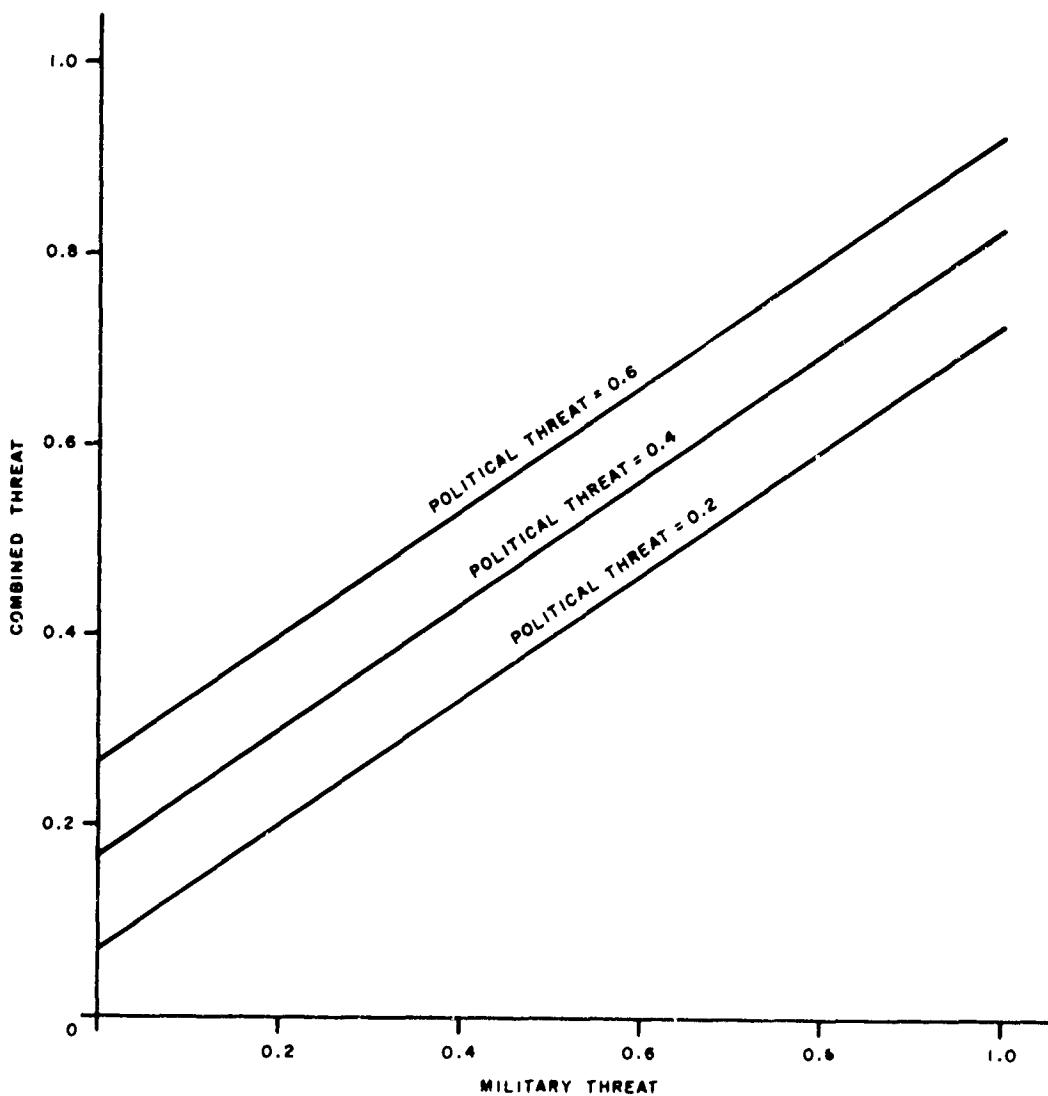


Figure 2-8 Military Threat versus Combined Threat
-53-

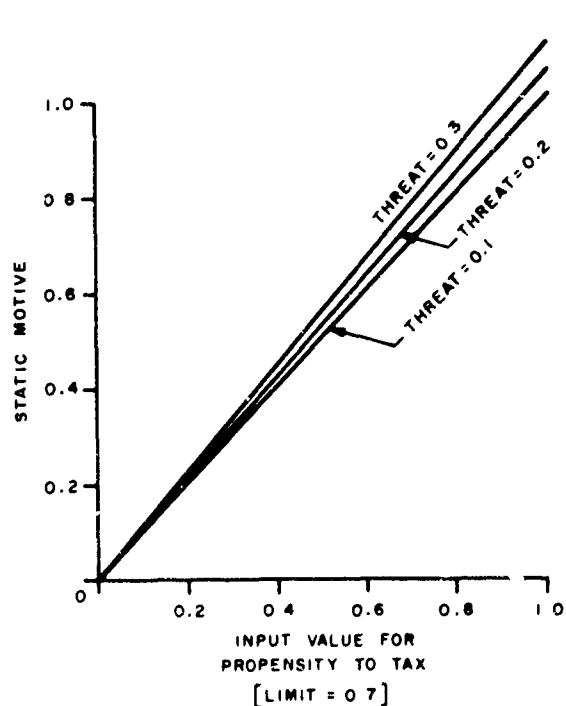
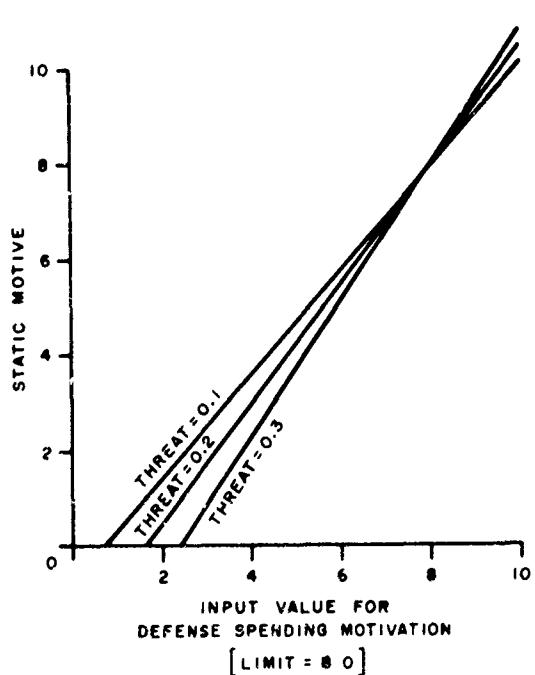
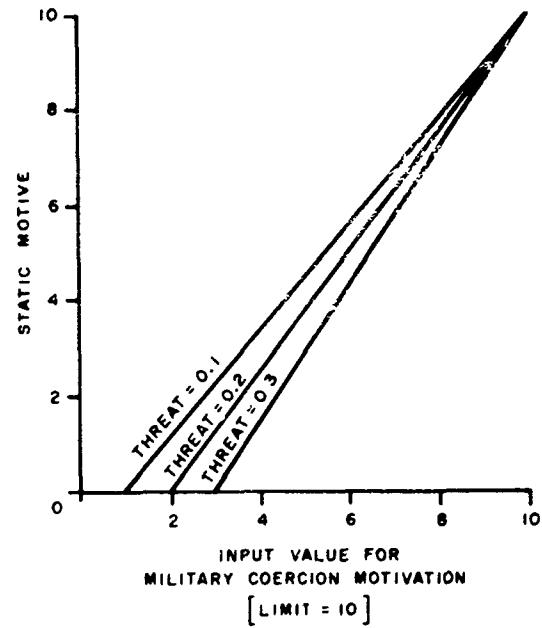
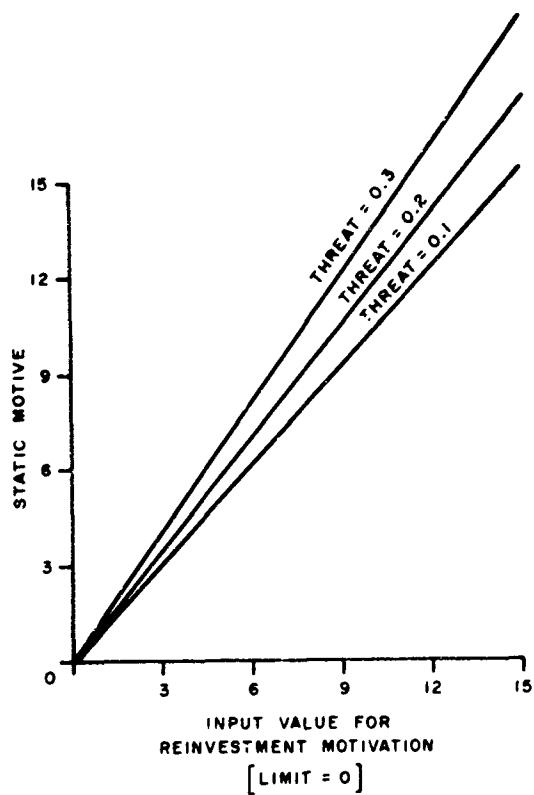


Figure 2-9 Static Motives as Function of Input Motivation and Day Zero Threat

The combined threat is used to compute the static motives, while the threat (or the components) and static motivations are used to compute external dynamism and military power ratio, and the other motivations. Since on the first run through KULTUR on day zero there is no threat, each of the computations relying on it is affected. Only the military power ratio motivation is used before the second time through on day zero, and the special case of the lack of threat will be discussed when that function is dealt with below.

The Static Motives are computed on day zero only (see Equation 2). On the second pass for day zero, tactical threat is present and a meaningful computation may be made. Static motives are used in the computation of motivation for:

- a. Internal initiative
- b. Military coercion
- c. Military initiative
- d. Propensity to tax

Figure 2-9 shows how the static motive varies as a function of the input motivation and day zero threat. For the present settings for the limits, the reinvestment motive will increase as day zero threat increases, and the military coercion motive decreases as day zero threat increases. For the defense spending motive and the propensity to tax motive, the shift will depend on whether the input motivation is greater or less than the limit. If less than the motive decreases as threat increases. If greater than the motive increases as threat increases. Usually the defense spending input motivation is set below the limit and the tax motive above. The further the input motivation is set from the limit, the greater effect day zero threat has on setting the static motive. If the input motivation is set at the limit for a Nation-Group, there will be no variance in motivation under different threats during the operation of the model. See Equation 3.

Motivations are set at day zero and each quarter by a common equation for each of the four motivation variables for which static motives are set. The formula (see Equation 4) results in a modified setting which deviates from the

static motive as a function of threat and limit (the level to which the value tends under conditions of threat). If there is no threat, then the static motive value is used for the new motivation value. If there were a complete threat (1.0), then the motivation would be set at the limit value for that motivation.

Power ratio motivations are computed for three types of spending; strategic, tactical, and R&D. (See Equation 5.) In practice, the function operates in a fashion similar to the motivation formula. The motivation is computed by finding the deviation from the aspiration level, assuming no threat. The aspiration levels are similar to the static motive and limit. They are assumed to be different for each bloc leader and are set as parameters when the Data Base is set. In the current Data Base, they are set so that there is a greater range of aspiration levels for the U.S. than for the Soviet Union, and therefore a greater sensitivity and response to threat. Lack of threat drives the function to one level. Threat drives the value toward a second aspiration level. The perception routine requires that the power ratio motivations be computed before the perception day zero routine. Since threat requires perception, this first power ratio motivation computation is done with no threat. Therefore, power motivation ratios for all three kinds of expenditure are set to the aspiration level assuming no threat. On the second pass for day zero, KULTUR has a threat and a more complete power ratio motivation is made available for the first quarter computation in PERCEP.

2.4.3 Equations in KULTUR

1. Combined Threat = $\frac{\text{Total Political Threat} + 2 \text{ Total Military Threat}}{3}$

2. Motive = $(\text{Input Motivation} - \text{Limit} \times \text{Threat}) / (1 - \text{Threat})$

3. For updating External Dynamism,

$$\begin{aligned} \text{Updated Motivation} &= \text{Previous Motivation} \times (1 - \text{Military Threat} \\ &\quad + \text{Political Threat}) \end{aligned}$$

4. Motivation = Static Motive + (Motivation Limit - Static Motive) x Threat

5. Power Ratio Motivation = Aspiration Level_O + Threat (Aspiration Level_M - Aspiration Level_~)

Where aspiration level is a limit toward which the tend and where O represents the absence of threat a threat. ratio motivation will the condition of total

Power motivations are calculated for three types of spending--strategic, tactical, and R&D. Limiting values are the aspirations under no threat (maximum) and under total threat (minimum).

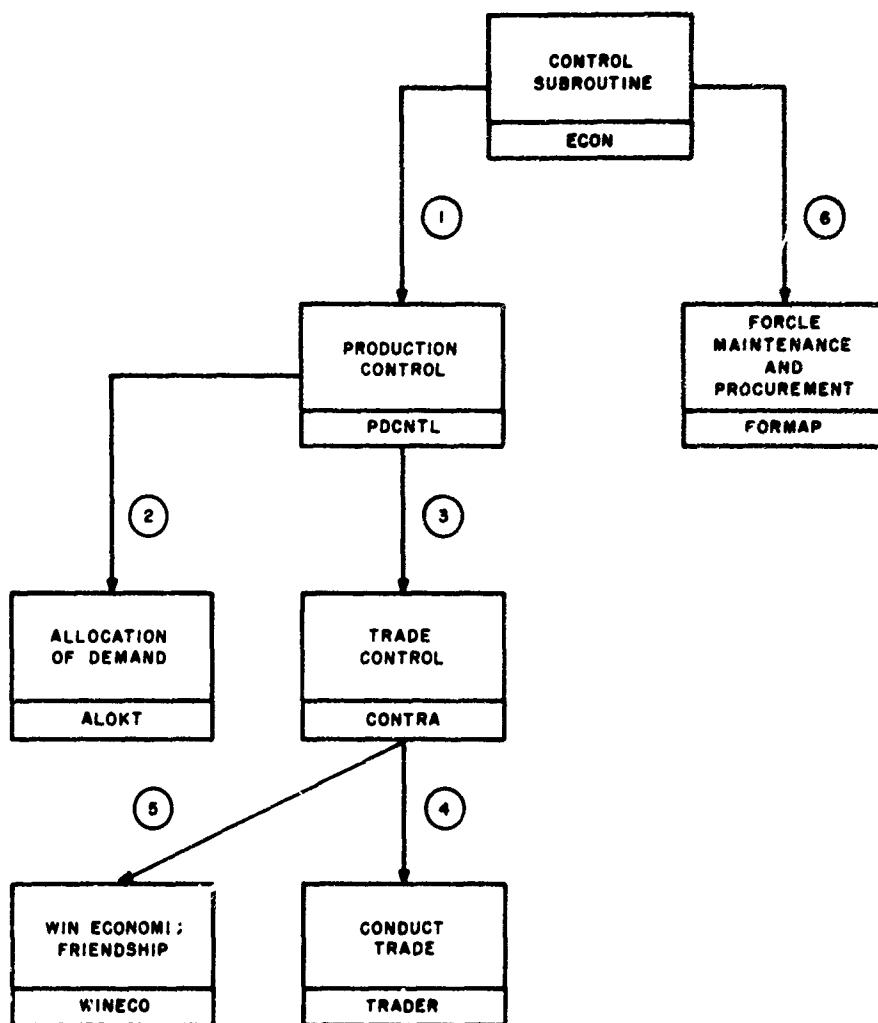
3.0 The Economic Submodel

The Economic Submodel is operated by Control Subroutine ECON. ECON itself does not operate on the Data Base. Its purpose is to sequence the subroutines which embody the simulation of the economic factors of the world. Figure 3-1 shows the subroutines controlled by ECON and their relationship to one another. Three basic functions of the Economic Submodel are performed in the order given:

1. For each Nation-Group establish production, consumption and surplus inventory or unsatisfied demand for both public and private purposes within each of the six economic sectors.* This function is performed by Subroutine PDCNTL (Production Control) assisted by Subroutine ALOKT (Allocation Demand).
2. Conduct international trade. A Nation-Group attempts to strengthen declining friendships by selling its surplus inventory to the Nation-Groups withdrawing friendship, provided they have matching unsatisfied demands. Similarly, to satisfy its own demands a Nation-Group purchases from the matching surpluses of its friends. These functions are performed by Subroutine CONTRA (Trade Control), Subroutine TRADER (Conduct Trade), and Subroutine WINECO (Win Economic Friendship). CONTRA is sequenced by PDCNTL.
3. Operate, maintain, and procure military forces. Subroutine PDCNTL establishes a military budget for each Nation-Group. This budget is used first to cover operating and maintenance costs of existing forces. Any remaining funds are used to purchase additional forces. A deficit causes incomplete maintenance, no procurement of new forces, and depreciation of existing forces. These functions are performed by Subroutine FORMAP (Force Maintenance and Procurement).

On day zero the Economic Submodel operates to set certain parameters. Thereafter, it is called the last week of each quarter. The subroutines listed above are described in the following sections of this chapter. A detailed discussion of the FORTRAN coding, and numerical examples may be found in Chapter 3 of Volume IV, which parallels the organization of this chapter.

*The six economic sectors into which the total economy of a Nation-Group is divided are: military, light industry, heavy industry, agriculture, natural resources, and services.



NOTES :

1. THE CIRCLED NUMBERS INDICATE THE ORDER IN WHICH THE SUBROUTINES ARE CALLED.
2. UPON COMPLETION OF A SUBROUTINE CONTROL RETURNS TO THE SUBROUTINE THAT INITIATED THE CALL. THUS, UPON COMPLETION OF WINECO CONTROL RETURNS TO CONTRA, THENCE TO PDCNTL, AND FINALLY, TO ECON.

Figure 3-1 The Subroutines of the Economic Submodel

3.1 Subroutine Production Control (PDCNTL)

3.1.1 General Description of PDCNTL

Subroutine PDCNTL simulates the economy of each of the Nation-Groups. Capital, labor, and natural resources are used to produce inventories in each of the six economic sectors. The production is added to surplus inventory from the previous quarter. Public and private demand in each sector are then computed, and as much as possible of the demands are satisfied from the inventories. Excess inventory (except military and services sectors) is available for export, and will cause reduced production during the next quarter. Contrarily, as much as possible of any excess demand in a given economic sector is satisfied by importing. Since excess demand indicates depleted inventory, production is increased during the next quarter. When a Nation-Group is threatened it will tend to divert funds from long-range capital investment to more immediate production requirements. In times of peace it will reinvest to increase capital wealth. All Nation-Groups experience an increase in the size of their work forces with the passage of time.

3.1.2 Detailed Description of PDCNTL

Subroutine PDCNTL updates GNP, growth rate, work force, and capital worth each quarter. Spending is divided into public and private by use of the tax rate motivation to determine the fraction of GNP allocated to public purchases. Production is computed in each of the six sectors which make up the total economy:

- a. Military
- b. Heavy industry (capital goods)
- c. Light industry (consumer goods)
- d. Agriculture
- e. Natural Resources (mining)
- f. Services

New production is added to the inventory remaining from the previous quarter, and the result is compared with new demand, plus any unsatisfied demand from the previous quarter. Purchasing is a function of demand scaled so that purchasing does not exceed inventory. Private demand may be satisfied in part by international trade, but not government demand. The amount of trade demand is computed by PDCNTL which then uses Subroutine CONTRA, described in Section 3.3 to attempt the desired trade. Final inventories and unsatisfied demands are used to decrease or increase production in the next quarter.

The total value of goods produced in all six sectors of the economy is called quarterly gross national product.* The rate of GNP growth is computed once each year on the basis of willingness to reinvest, capital depreciation, and total GNP. The public and private demands are allocated according to a schedule (stored in Subroutine ALOKT) which is a function of average take-home pay and the tax rate.

Demands are compared with inventory levels and purchases are made equitably between the public and private consumers. If private demand in a given economic sector exceeds supply, demand is created for imports in the sector in short supply. If supply exceeds demand, inventory is built up and made available for export. Final inventories and unsatisfied demands are used to curtail or increase production respectively for the next cycle. Unsatisfied government demand is added to the demand computed at the end of the next quarter, and no attempt is made to satisfy it by importing.

Government expenditures for other than defense spending are allotted the funds remaining after all military purchases have been made. Defense spending is governed by a command generated in Subroutine BUDGET once each year which determines the slice of government spending for defense. Details of the spending of the military budget will be found in Section 3.6, Subroutine FORMAP

*This quantity will be referred to as GNP.

The relationship of GNP to capital depreciation and growth reflects threat. As threat increases, new investment, as a percent of GNP, decreases resulting in a loss in the rate of capital increase. Stability is achieved in the model by using the internal initiative motive as the static driver for GNP growth coupled to capital through threat. Production control is achieved by changing the allocation of capital between the six economic sectors. The defense sector receives the capital it needs to satisfy demand. The remaining capital is distributed to the remaining sectors in response to both unsatisfied demand, and surplus inventory.

3. 1. 3 Equations in PDCNTL

The equation used to determine production for each of the six sectors of the economy is:

$$1. \quad P_i = (M \times W \times M_i) + (RU_i \times RDR \times R) + (CU_i \times DPR)$$

where 6

$$\sum P_i = GNP$$

$i = 1$

P_i = Production in sector i

W = Average wage

M_i = Manpower Fraction/sector i

M = Total work force

RU_i = Resource use fraction/sector i

RDR = Resource depletion rate

R = Resource wealth

CU_i = Capital use/sector i

DPR = Total depreciation

In other words, the value of goods produced is the sum of labor costs, plus raw material, plus capital depreciation. The current production is added to the surplus to obtain the inventory.

1a. $I_i = I_s + P_i$

where

I_i = the inventory.

I_s = the previous surplus, which may be zero.

Capital depreciation, DPR, used in (1) is computed as follows:

2. $DPR = C_t (DI + W)$

where

C_t = Total capital.

DI = Diversion index, the fraction of capital consumed to meet high threat.

W = Wear-out fraction, the fraction of capital which wears out, or depreciates during one quarter.

Resources depletion rate RDR, used in (1) is computed as follows:

3. $RDR = R_t \times U$

where

R_t = Total natural resources (i. e., raw materials) on hand.

U = The fraction consumed during the current quarter.

The work forces of all Nation-Groups are assumed to increase 1/4 percent each quarter.

4. $\Delta M_t = 0.0025 M_t$

where

ΔM_t = the increase in the work force.

M_t = the total work force

5. All workers in a Nation-Group are assumed to receive the same wages. It is computed at day zero from the input annual GNP.

$$W = 1/4 (\text{Annual GNP}) - \text{DPR} - \text{RDR} \text{ (on day zero only)}$$

6. Quarterly GNP is the sum of the production in each of the six sectors. 6

$$\text{GNP} = \sum_{i=1}^6 P_i$$

7. The average tax bill, B, is given by:

$$B = \frac{(T \times (\text{GNP}) + D_g)}{M_t}$$

where

T = Tax rate motivation.

D_g = Government demand unsatisfied at the end of the previous quarter.

8. The average take home pay, PAY, is given by:

$$\text{PAY} = \frac{\text{GNP}}{M_t} - B = \frac{\text{GNP} (1 - T) - D_g}{M_t}$$

In other words, take home pay is the worker's share of GNP after allowing for current and deferred government demand.

The government demand fraction gd, and private demand fraction, pd, for each economic sector are supplied to PDCNTL by Subroutine ALOKT.

9. $gd_i = f(B)$

10. and $pd_i = f(\text{PAY})$

The demand in dollars in each sector of the economy is obtained by multiplying.

$$11. \quad GD_i = gd_i [(T \times \text{GNP}) + D_g]$$

$$12. \quad PD_i = pd_i [\text{GNP} (1 - T) - D_g]$$

Note: Compare (11) with (7) and (12) with (8).

GD_i = Government demand in sector i

PD_i = Private demand in sector i .

The Decision Maker Submodel (in Subroutine PROREC) has generated a private trade demand factor, td_i , as a function of inventory remaining, unsatisfied demand, and the balance of payments. It is used to compute the trade demand in each sector, TD_i , which will be used to adjust private demand.

13. $TD_i = td_i (GNP)$

If

$$TD_i > PD_i$$

let

14a. $TD_i = PD_i$; then let $PD_i = 0$

If

$$TD_i < PD_i$$

then reduce PD_i by the amount of TD_i and set TD_i to zero, i.e.,

$$PD_i \text{ final} = PD_i \text{ initial} - TD_i \text{ initial}$$

14b. $TD_i \text{ final} = 0$

Equation (14a) says that the trade demand, the amount Decision Maker thinks should be imported, exceeds the internal demand. By setting the internal demand to zero, PDCNTL in effect will attempt to satisfy the demand entirely from imports. Equation (14b) has the effect of reducing the internal (private) demand by the amount which it is hoped will be imported.

Total demand, and inventory in each sector are now compared.

If

$$GD_i + PD_i > I_i$$

let

$$G_i = \frac{GD_i}{GD_i + PD_i} (I_i)$$

and

15a. $P_i = \frac{PD_i}{GD_i + PD_i} (I_i)$

On the other hand, if

$$GD_i + PD_i \leq I_i,$$

let

$$G_i = GD_i$$

and

15b. $P_i = PD_i$

where

G_i is the government purchasing and P_i is the private purchasing in the i -th sector of the economy. * It can be seen that Equation (15a) is scaling the demands downward when inventory is inadequate to meet total demand. The value for D_{gi} (See Equation (7)) which will be used the following quarter is computed now.

16a. $D_{gi} = GD_i - G_i$

and

16b. $D_{pi} = PD_i - P_i$

where

D_{pi} is unsatisfied private demand. Clearly, if inventory in the i -th sector is adequate, both D_{gi} and D_{pi} will be zero. D_{pi} will be used by Subroutine TRADER to find buyers for surplus inventory.

* G_1 is government military spending, and will be used by Subroutine FORMAP. Likewise, P_1 always equals zero (i.e., no private military spending).

The capital use fraction used in Equation (1), CU_i , is reset for use at the end of the next quarter to reflect the production balance of the current quarter.

$$17. \quad CU_{i \text{ next}} = CU_{i \text{ current}} \frac{GD_i + PD_i + TD_i}{I_i}$$

The capital use fraction for the military sector of the economy is left as computed in Equation (17). The remaining five factors are normalized so that the sum of the six will be unity.

Purchases are subtracted from inventory. (See Equation (1a))

$$18. \quad I_s = I_i - G_i - P_i$$

If C_i and P_i were set by (15b), there will be a surplus, I_s , for export. Otherwise I_s will be zero.

Total unsatisfied government demand, D_g , and spending, G , are computed.

$$19. \quad D_g = \sum_{i=1}^6 D_{gi}$$

$$G = \sum_{i=1}^6 G_i$$

The resources, or raw materials, available for use during the next quarter are the sum of what was not used this quarter and newly developed resources as a result of private spending in sector 5. (See Equation (1))

$$20. \quad R_{\text{new}} = (1 - RDR) R_{\text{old}} + P_5$$

Each quarter estimates the annual GNP.

$$21. \quad \text{Annual GNP} = \frac{(Q - 1) (\text{Annual GNP}_{\text{previous}}) + (4)(\text{GNP}_{\text{current}})}{Q} \quad (21)$$

where Q is the number of the current quarter, i.e., 1, 2, 3, or 4.

In other words, annual GNP is taken as four times the weighted average quarterly GNP. At the end of each year, the annual growth rate, R_G , is computed.

$$22. \quad R_G = \frac{\text{GNP}_{\text{4th qtr}} - \text{GNP}_{\text{1st qtr}}}{\text{GNP}_{\text{1st qtr}}}$$

After Subroutine CONTRA has completed whatever trade is possible, PDCNTL updates the computation of capital. The incremental growth in capital is a function of the character of the Nation-Group (its propensity to reinvest) modified by the degree to which it feels threatened, and its annual GNP after deducting 10 percent from the surplus inventory to simulate real world losses from breakage, etc.

3.2 Subroutine (Demand Allocation) ALOKT

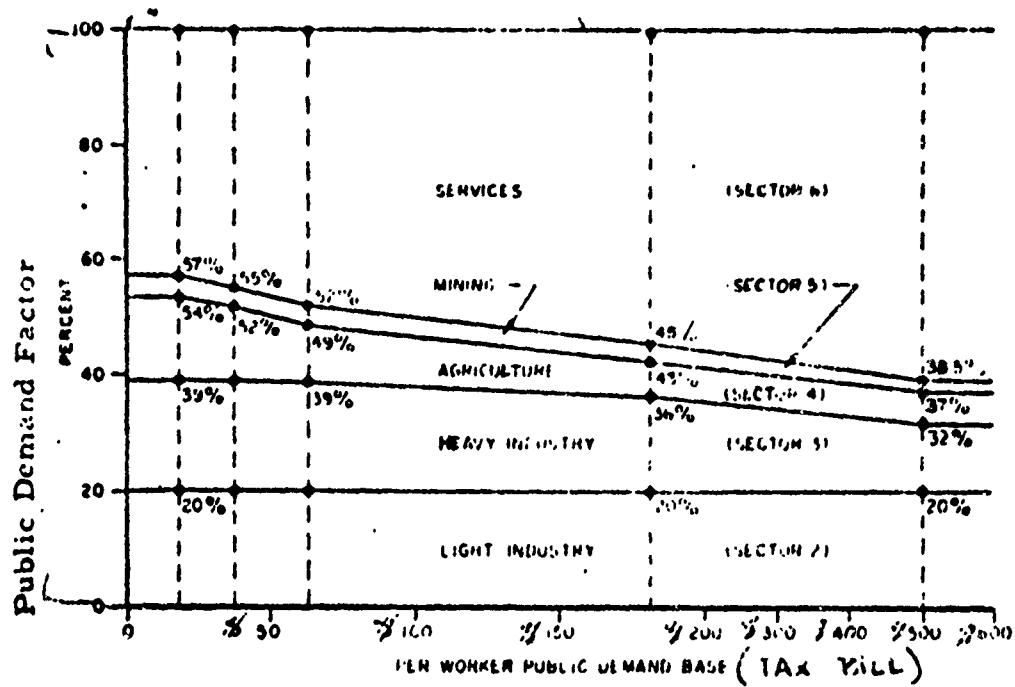
3.2.1 General Description of ALOKT

Subroutine ALOKT provides Subroutine PDCNTL (see Section 3.1 above) with the government demand per sector and the private demand per sector for each of six economic sectors. These sectors are as follows:

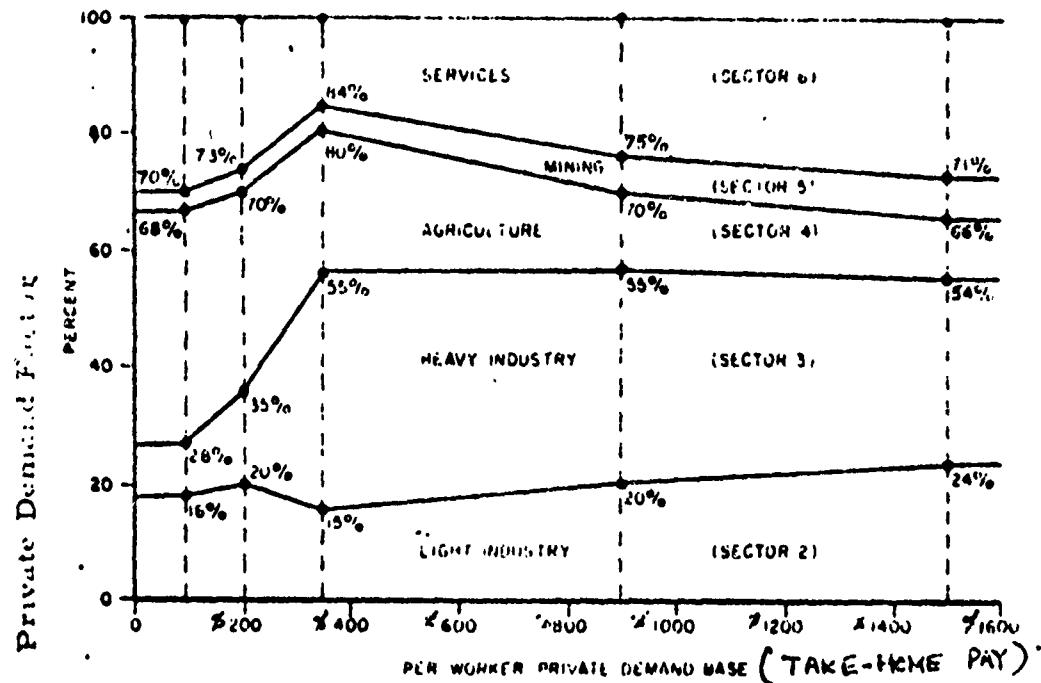
- a. Military
- b. Light industry (consumer goods)
- c. Heavy industry (capital goods)
- d. Agriculture
- e. Resource development (mining)
- f. Services

The government and private demand fractions are used to compute the fraction of the public and private purchasing power which becomes demand in each of the six sectors. (See Equations (11) and (12) in Section 3.1.3 above.) The factors are a function of the per capita tax bill and take home pay respectively, and are set as shown in Figure 3-2. The curves are based on W. W. Rostow's theory of The Stages of Economic Growth, which holds that all economies have the same growth properties independent of the form of government, and that as taxes and pay vary, the distribution of these resources will follow the curves.

The details of ALOKT will not be repeated here since the computer program merely stores the points shown in Figure 3-2 and interpolates between these points to find the specific values of the government and private demand fractions, corresponding to per worker public demand and per worker private demand computed in PDCNTL. As noted in Figure 3-2, private military demand is set to zero, and government demand in sectors two through six are adjusted to permit the government to buy as much military sector as it wishes to (within limits of available inventory) before distributing its remaining funds among the other sectors of the economy.



Note: The above values apply to the total demand after deducting the military demand (Sector 1) computed in Subroutine PDCNTL.



Note: Private demand for military spending is always set to zero.

Figure 3-2: Allocation of Public and Private Demand by ALOKT

3.3 Subroutine Control Trade (CONTRA)

3.3.1 General Description of CONTRA

Subroutine CONTRA has two basic purposes, political trade and residual trade, as shown in Figure 3-3, a flow diagram of CONTRA. It is based on the assumption that a nation will first use opportunities to export to regain declining friendship* and then will import to satisfy internal demand. CONTRA first attempts political trade for the Nation-Groups which have sustained the greatest losses in friendship in descending order of loss. It then attempts residual trade for the Nation-Groups with the greatest ratios of demand to GNP. CONTRA uses Subroutine TRADER to identify potential supplier-importer pairs where a surplus exists to satisfy a demand. No Nation-Group exports until it has satisfied internal demand, nor does it import if it has a surplus. The military and service sectors of the economy cannot be traded, although military aid is supplied directly by Subroutine SHIFT (Section 4.5).

3.3.2 Detailed Description of CONTRA

CONTRA is called by Subroutine PDCNTL which is described in Section 3.1. PDCNTL has computed the surplus inventory in each of the economic sectors that each Nation-Group has after completing internal purchasing. Ally value and alignment value have been updated by WINECO at the end of the previous quarter, by WINOVR during the previous week, and by THREAT during the current week. CONTRA checks the changes in these values to find the largest decreases, and then lists, in descending order, up to a maximum of 40

*TEMPER is concerned with the ability of bloc members to maintain a strong alliance, and to win the alignment of neutral nations. It records the value one bloc member places on another as an ally value, and the value a neutral places on a bloc member as an alignment value. Neutrals do not attempt to win bloc member friendship, so bloc members do not award alignment value to neutrals. In this section, friendship value will be used to mean either ally or alignment value as appropriate, although separate variables are used in the model.

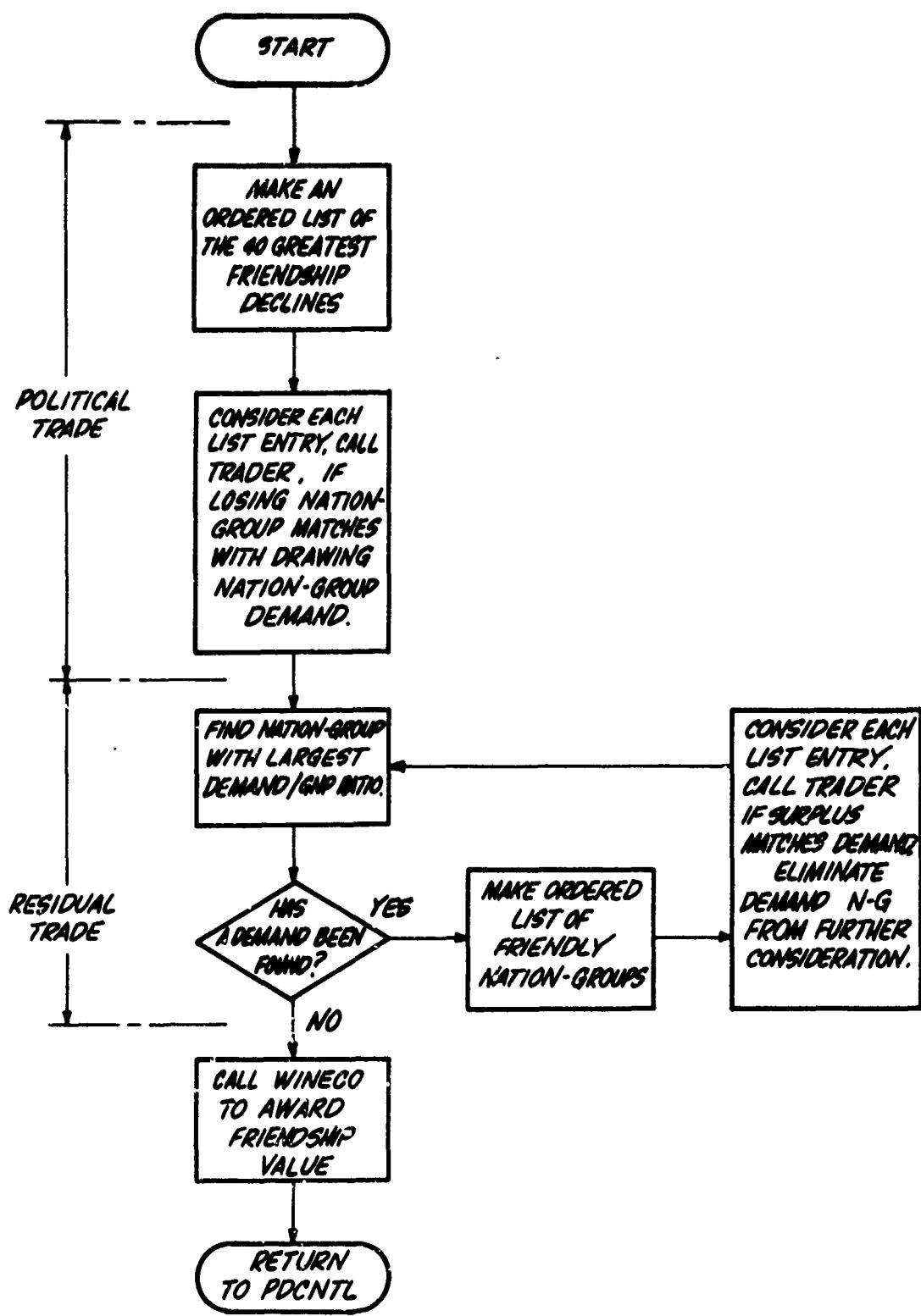


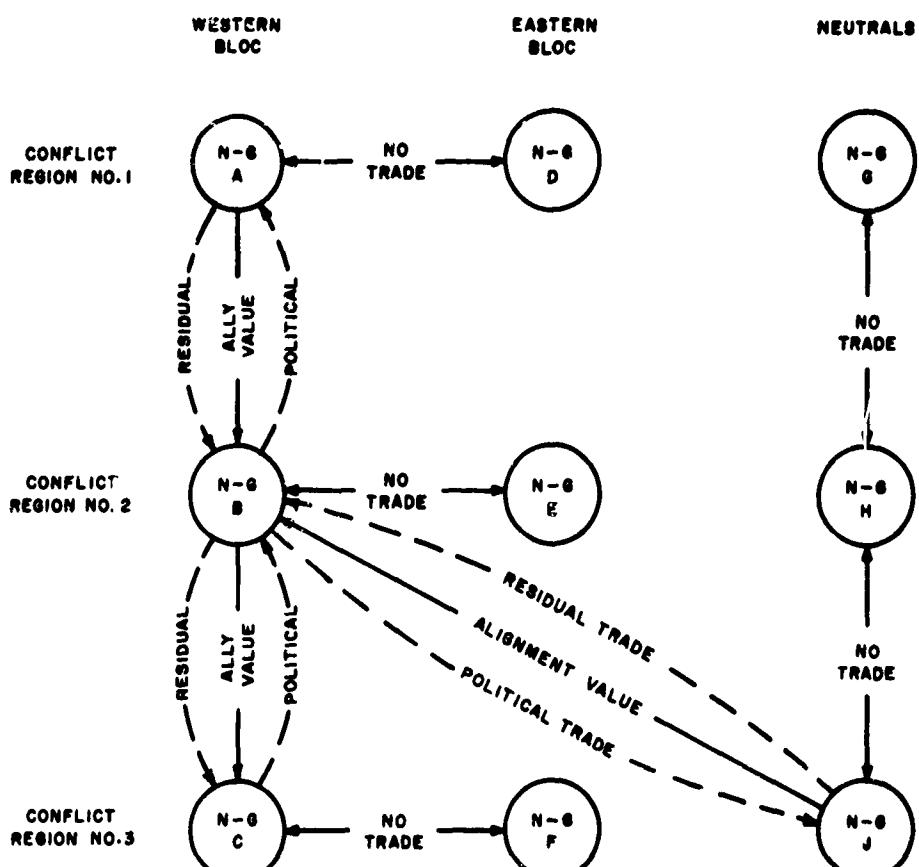
Figure 3-3 Simplified Flow Diagram of Subroutine CONTRA

pairs of Nation-Groups involved. Starting with the largest decrease on the list, CONTRA compares each of the demand sectors of the Nation-Group withdrawing the ally or alignment value with the surplus sectors of the Nation-Group which is trying to regain the lost friendship to see if a match can be found. Subroutine TRADER is called for each sector, and if it finds a match, the trade is carried out. This process (political trade) is repeated for all the other pairs of Nation-Groups on the list. Note that political trade can only flow from a Nation-Group awarded an ally or alignment value as shown in Figure 3-4.

CONTRA then attempts to find trades to meet unsatisfied demand (residual trade). It assumes that the Nation-Group with the largest unsatisfied demand in proportion to its GNP will be the most aggressive international trader. It identifies this Nation-Group and the sector in which the demand occurs. It then prepares a list in descending order of ally alignment values awarded by bloc members and CONTRA then has TRADER scan the list to see if any of the Nation-Groups on the list have a surplus inventory, and arranges for trade as appropriate. Each Nation-Group with a matching surplus will export in proportion to its surplus and its degree of friendship for the demand Nation-Group. Note that this trade (residual trade) can only flow from a Nation-Group awarding ally or alignment value. CONTRA continues this process with the next smaller demand until it has considered all demands larger than a preset threshold.

It then calls Subroutine WINECO (Win Over Economically). WINECO uses the list of trades completed during the current week to make appropriate increases in the ally and alignment values to the Nation-Groups conducting the trade. It must be remembered that residual trade can only flow from the donor to the recipient of ally or alignment value, political trade can only flow in the opposite direction and that these donor-recipient relationships are set at the beginning of the game by the composition of each of the Nation-Groups, and no new ones are created.

Figure 3-4 shows a simplified TEMPER world of nine Nation-Groups with potential trade avenues shown. Nation-Group (B) has received ally value from Nation-Group (A) i.e., Nation-Group (A) values its alliance with Nation-Group (B). Nation-Group (B) has a similar relationship with Nation-Group (C).



NOTE:

THE TRADE VECTORS INDICATE THE DIRECTION IN WHICH THE GOODS FLOW. THE VALUE VECTORS SHOW THE DIRECTION FROM DONOR TO RECIPIENT

Figure 3-8 Possible Trade Relations Between Nation-Groups

Nation-Group (J), a neutral, has valued its alignment with Nation-Group (B). However, had it lowered the value of this alignment significantly, Nation-Group (B) would respond by trying to buy the surplus inventory of (C) and satisfying the unsatisfied demand of (C), so as to restore the declining alignment. It is the purpose of CONTRA and TRADE to seek these trade avenues, and if surplus and demand match, to carry out the trade. Since West and East do not award ally value to one another, there is no trade between the blocs. Similarly, neutrals do not award one another alignment value, and so do not trade with one another.

3. 3. 3 Equations in CONTRA

CONTRA itself does not change any of the variables in the Data Base. The trade bookkeeping is done for it by Subroutine TRADER, and the ally and alignment value tables are updated by Subroutine WINEC).

3.4 Subroutine Trading (TRADER)

3.4.1 General Description of TRADER

Subroutine TRADER has been designed to carry out both political and residual trade as directed by Subroutine CONTRA which calls it. Political trade consists of an attempt by one Nation-Group to buy the surplus inventory of another Nation-Group in all tradable sectors of the economy. Residual trade is an attempt by a Nation-Group to satisfy its own demand in a particular sector of the economy by buying from the Nation-Groups which have awarded friendship* value to it. TRADER is given the identity of the importing Nation-Group, the sector of the economy, and a list of potential suppliers (Nation-Groups who have awarded friendship to the importer) by CONTRA. If the trading is political, only the Nation-Group which has reduced its friendship is on the list. TRADER then scans the list from top to bottom. If the supplier has a surplus in the sector identified, the trade takes place. TRADER does this by reducing the importer's demand, the importer's balance of payments, the supplier's inventory, and by increasing the supplier's balance of payments. Finally, TRADER makes a record of the trade for later use by Subroutine WINECO.

*As in Section 3.3, friendship value is taken to mean either ally value or alignment value as appropriate.

3.4.2 Detailed Description of TRADER

Considering first residual trade, TRADER is given an ordered list of friends for the potential importer by CONTRA. It starts at the top of the list, i. e., the Nation-Group which has awarded the highest friendship value to the Nation-Group with the demand, and makes it a potential supplier. If the supplier has an inventory in the same sector as the importer's demand, it performs the necessary bookkeeping to effect the trade. It will be recalled that the production of each Nation-Group was added to its inventory by PDCNTL as described in Section 3.1. PDCNTL then subtracts government and private purchases. This implies that in the TEMPER world, internal demands are satisfied as much as production and stockpiles permit, before any goods are exported.

The amount actually shipped is a function of demand, and relative inventory and friendship. Specifically

$$T = \min \left\{ D, \frac{I_1 \cdot F_1}{\sum_{i=1}^n I_i F_i} \cdot I_1 \right\}$$

$$\sum_{i=1}^n I_i F_i$$

where

T = amount of goods imported from the most friendly potential supplier.

D = the importer's demand.

I_1 = the inventory of the most friendly potential supplier.

F_1 = the friendship value awarded by the most friendly potential supplier.

n = number of potential suppliers.

The function states that the supplier will supply the smaller of either its entire inventory, or a fraction of the demand which is proportional to the ratio of its inventory to the total available inventory, both weighted by the relative friendship of each potential supplier. The total weighted available inventory is given by the term:

$$\sum_{i=1}^n I_i F_i$$

In other words, if all suppliers are equally friendly each will export in proportion to its share of the supply available to the importer. On the other hand, if one supplier is much more friendly, it will provide a greater portion of the trade.

When the trade has been established, TRADER decreases the importer's demand and the supplier's inventory by the amount traded and adjusts the balance of payments of both Nation-Groups appropriately. If the amount of the trade exceeds a threshold, the amount of the trade and the supplier and importer are noted on a list which will later be used by WINECO as described in Section 3.5 below. TRADER then checks the next entry, on the potential supplier list from CONTRA. If there is no entry, it repeats the steps above and so on, until all potential suppliers have been checked. If the total available inventory exceeds the demand, the demand will be satisfied with imports coming from all the potential suppliers having an inventory. This process is shown graphically as Residual Trade in Figure 3-5.

Political trade is carried out in the same way by TRADER, but the inputs furnished by CONTRA are quite different because of the different purpose. The subject Nation-Group, the one from which the friendship has been withdrawn, is now identified as the potential supplier, and the only potential supplier. CONTRA tells TRADER that the potential supplier has awarded the potential importer a friendship value of unity when, in fact, the value may be something else or not existing at all. Likewise, the object Nation-Group is identified as the potential importer. Finally, rather than specify a single economic sector, CONTRA specifies each one in turn as it calls TRADER. If these changes are factored into the expression for trade given above, we see that it reduces to:

$$T = \min (D, I_1)$$

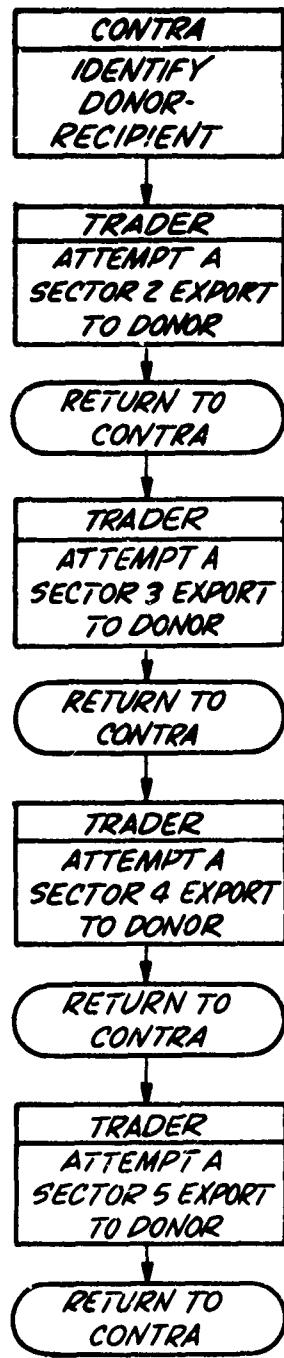
In other words, TRADER will attempt to fully satisfy the demand (i.e., achieve the political objective of the subject Nation-Group). This process is shown graphically as Political Trade in Figure 3-5.

3.4.3 Equations in TRADER

$$T = D \left[\frac{I_1 \cdot F_1}{\sum_{i=1}^n I_i \cdot F_i} \cdot I_1 \right]$$

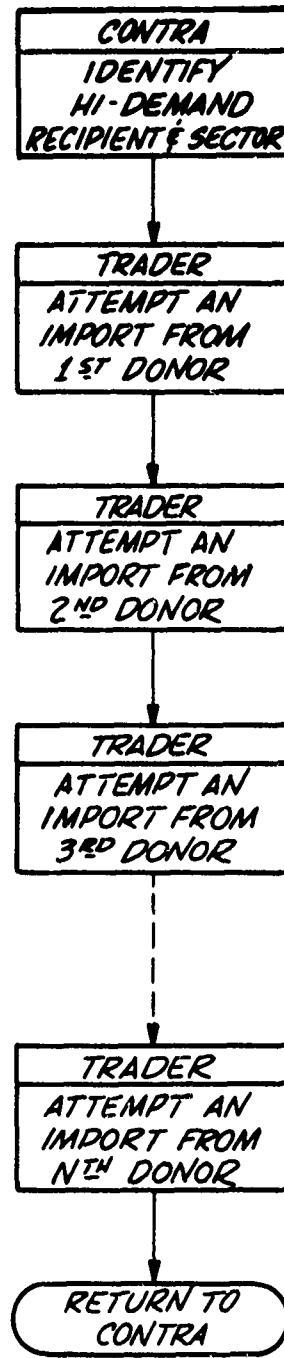
unless I_1 is less in which case the value for I_1 is taken.

OBJECTIVE:
REGAIN DECLINING
FRIENDSHIP



POLITICAL TRADE

OBJECTIVE:
SATISFY
DEMAND



RESIDUAL TRADE

Note: Donor = Donor of alliance or
alignment value

Recipient = Recipient of alliance
or alignment value

Figure 3-5 The Differences Between Political and Residual Trade

3.5 Subroutine Win Over Economically (WINECO)

3.5.1 General Description of WINECO

Subroutine WINECO has two functions. The first is to reset to zero the tables of ally value change and alignment value change at the beginning of each quarter. This prepares the tables for the recording of the weekly changes which are accumulated during the ensuing quarter. If two Nation-Groups have no relations during the period, it will be found that there is no change recorded.

The second function is to increment ally or alignment values to reflect the trading just completed by TRADER. WINECO scans the list of trades and increments the values in the ally and alignment value change tables in proportion to the amount of trade and previous value of the ally or alignment value.

3.5.2 Detailed Description of WINECO

Subroutine WINECO first sets all entries in the tables of ally value change and alignment* value change to zero. In effect, the slate is wiped clean at the beginning of each quarter, and the indication of change (that is, the trend of the friendship value accumulated in weekly increments and stored in the TEMPER Data Base) will reflect only what happens during the current week. At the end of the next quarter, the ECON Submodel is again called, and Subroutine CONTRA again undertakes political trading, based on the friendship trends established during the preceding twelve weeks. History prior to the quarter is ignored.

The second function of WINECO is to award friendship value for the trade completed by Subroutine TRADER during the current week. The list of trading activity prepared by TRADER is reviewed. If the amount of trade differs from the amount conducted at the end of the previous quarter, ** the friendship value is adjusted as follows:

*As in previous sections, friendship will be used to mean either ally value (one bloc member to another), or alignment value (a neutral to a bloc member), as appropriate.

**This second WINECO function is skipped when WINECO is operated at the end of the first quarter since there is no previous trade with which to compare the current trade.

If trade increased:

$$1. \quad F_{\text{new}} = F_{\text{old}} + (1 - F_{\text{old}}) (\tanh T)$$

If trade decreased:

$$2. \quad F_{\text{new}} = F_{\text{old}} (1 + \tanh T)$$

where:

F_{new} = the new friendship value

F_{old} = the old friendship value

T = Trade Change Function, defined as:

$$T = \frac{\Delta T}{\frac{GNP}{kD}}$$

where:

T = Amount of trade of current quarter less amount of trade of previous quarter.

GNP = the quarterly GNP of the importer

k = a constant, currently set equal to 10.

D = external dynamism of importer.

Figure 3-6 shows the relationship parametrically. It can be seen that if ΔT is negative, i.e., the amount of trade has decreased, the friendship value will also decrease. If ΔT is not large compared with GNP, that is the amount imported was too small to have much impact on the economy, the change in friendship value is small. A Nation-Group with a high external dynamism responds less to imports and awards less friendship value than a Nation-Group with a lower external dynamism. Note that the response to an increase in trade by Nation-Groups as a function of previous friendship value is the inverse of the response to a decrease. In other words, a close friend awards few additional points for increased trade, but withdraws many more points for a decline in trade of the same amount.

When WINECO has made all friendship value adjustments, it eliminates the record of the previous quarter's trading in the Data Base, and substitutes the current record of trading in its place, ready for comparison when WINECO is called the following quarter. Control then returns to CONTRA. As this is the final function of CONTRA, it returns control to PDCNTL.

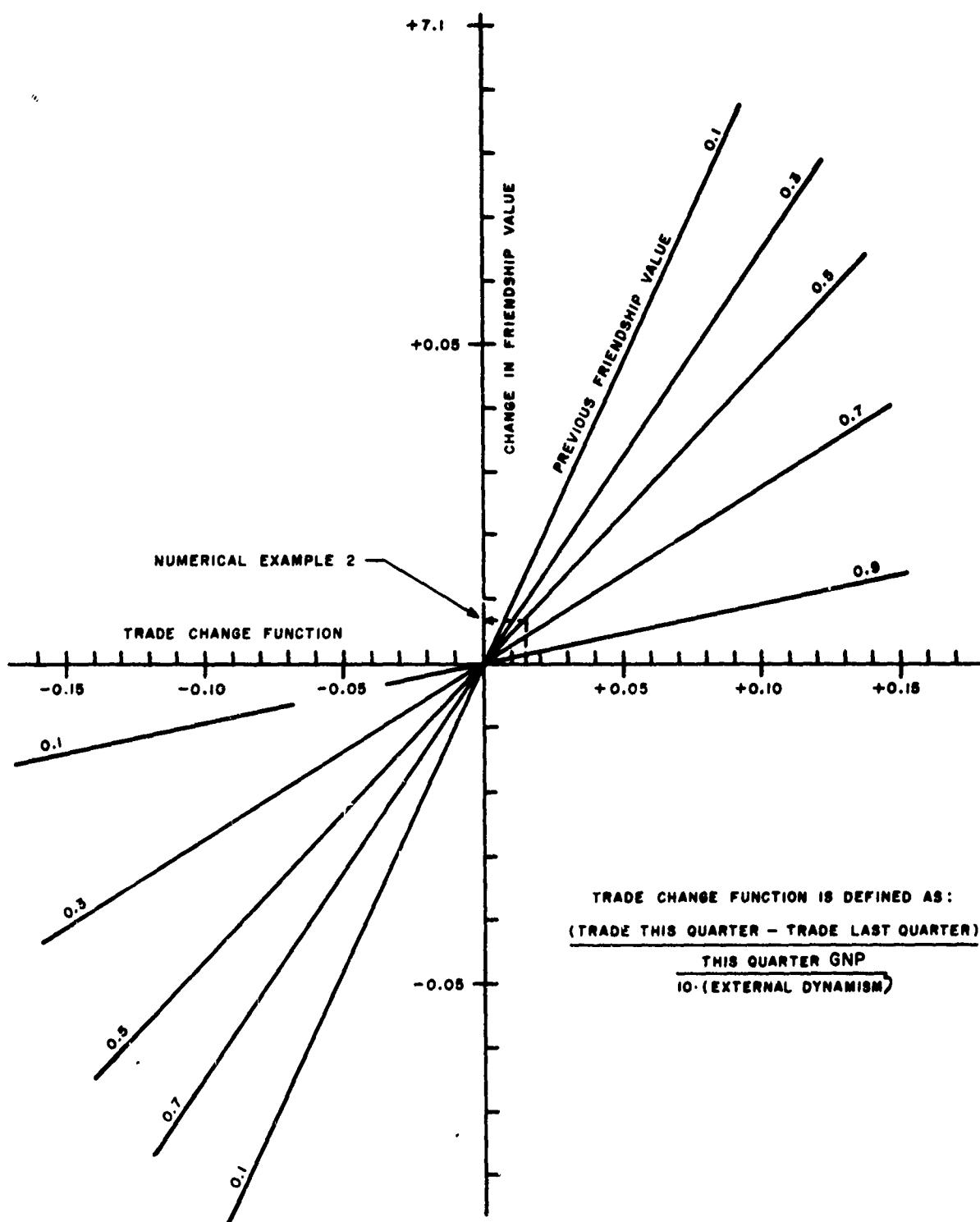


Figure 3-6 Friendship Value Change Function

3. 5. 3 Equations in WINECO

$$1. \quad F_{\text{new}} = F_{\text{old}} + (1 - F_{\text{old}}) (\tanh T)$$

$$2. \quad F_{\text{new}} = F_{\text{old}} (1 + \tanh T)$$

where:

F_{new} = the new friendship value.

F_{old} = the old friendship value.

T = Trade Change Function, defined as:

$$T = \frac{\Delta T}{\frac{GNP}{kD}}$$

and where:

ΔT = Amount of trade of current quarter less amount of trade of previous quarter.

GNP = the quarterly GNP of the importer.

k = a constant, currently set equal to 10.

D = external dynamism of importer.

3.6 Subroutine Force Maintenance and Procurement Subroutine (FORMAP)

3.6.1 General Description of FORMAP

The procurement of new military forces takes place at the end of each quarter of TEMPER time and is governed by the amount of defense funds made available in Subroutine PDCNTL (described in Section 3.1), and by the procurement ratios established for each Nation-Group in the Decision Maker Submodel (described in Section 5).

Procurement will not take place if the current, total, operations and maintenance cost of one's forces exceeds the available dollars in the defense budget. When this occurs depreciation of all forces takes place, but at a different rate for each of the two types, strategic and tactical. The operating and maintenance costs are scaled to represent not only current operating costs, but, also, replacement costs, so that the model assumes that obsolete systems are continuously replaced with newer ones as funds permit.

Of the two basic types of forces, tactical and strategic, all Nation-Groups have tactical forces and a budget for their support. A small number of Nation-Groups, not exceeding six, including the two bloc leaders, also have strategic forces with corresponding strategic force budgets. These Nation-Groups are called "strategic owners". The model assumes that only bloc members will be strategic owners, and the simulation is so implemented.

The tactical force types are:

- a. Tactical air wings
- b. Reorganization Objective Army Division (ROAD) divisions
- c. Paramilitary divisions
- d. Nuclear army division
- e. Navy forces

The strategic force types are:

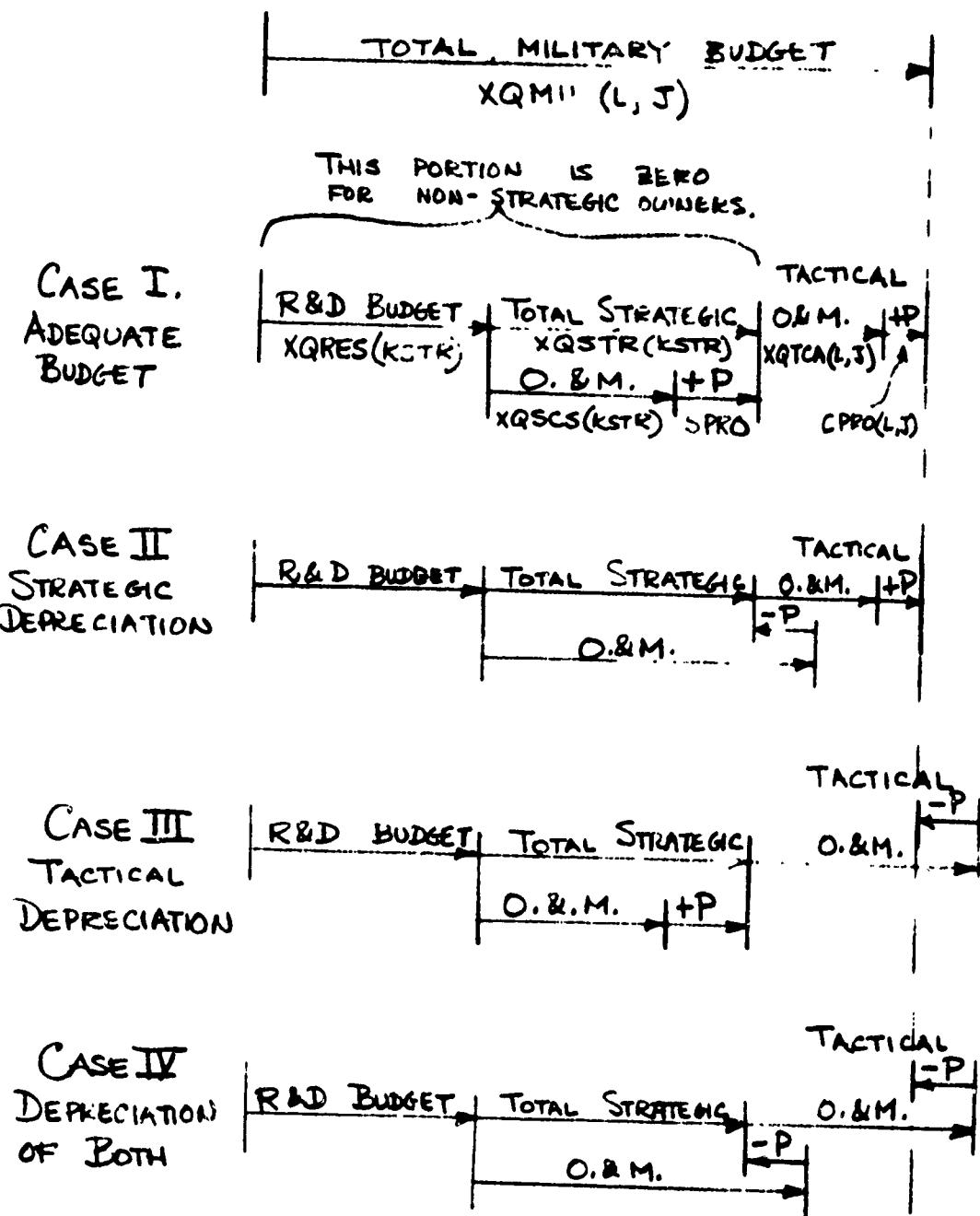
- a. Hidden Intercontinental Ballistic Missiles (ICBM's)
- b. Located Intercontinental Ballistic Missiles (ICBM's)
- c. Strategic air wings
- d. Submarine Launched Ballistic Missile (SLBM) submarines

3.6.2 Detailed Description of FORMAF

The total military budget is set in the last week of each quarter by Subroutine PDCNTL. When the total military budget is adequate, the amount available for tactical force procurement is found by deducting the tactical force operations and maintenance (O&M) costs (for the quarter just ending) from the total military budget, in the case of Nation-Groups that are not strategic owners. The strategic owners must deduct in addition, the percentages of the total budget desired for R&D spending and for support of strategic forces. The strategic procurement budget is found in turn by subtracting the strategic forces O&M cost from the amount determined above for support of strategic forces (see Section 3.6.3).

If the O&M costs are greater than the budget for either strategic or tactical forces, the inventory of the forces is reduced. This simulates the declining effectiveness of inadequately maintained forces. These relationships are shown graphically in Figure 3-7 and are discussed in detail below.

The remaining functions of FORMAF are (1) to update the force inventories to reflect either new procurement, if budgets permit, or depreciation, if budgets are inadequate, and (2) to compute operating costs for the new inventories. The procurements or depreciations are effected at the end of the quarter with the funds remaining or, in the case of depreciations, by the amount of shortage after O&M costs for the quarter just ending have been paid. This establishes the size of the forces for use during the following quarter. Consequently, new O&M costs for the following quarter can now be calculated and will be used in determining the new budget. These costs will be paid at the end of the ensuing quarter. The unit costs for operating and procuring each of the nine force types are parameters fixed at the beginning of the game. They are not a function of time or the location of the force. Furthermore, operating costs of tactical forces do not increase when these forces enter combat. These simplifying assumptions were made in designing TEMPER so that emphasis could be placed on the cold rather than the hot war aspects of conflict. Since TEMPER does not attempt to simulate inflation, one may expect prices to remain stable.



O&M equal operating and maintenance cost + P equals positive balance available for new procurement -P equals "negative" procurement.

Figure 3-7 Disposition of the Military Budget by FORMAP

If land forces have been deployed to another Nation-Group as military aid, the owner Nation-Group pays the O&M cost. If the procurement budget for the owner Nation-Group is negative, its overseas forces are depreciated, but they are not increased if the budget is positive. Transport units are purchased with a portion of the tactical forces budget. Each Nation-Group is given an initial inventory of transport units, some of which may be lost to enemy naval action. If the tactical forces procurement budget is positive, the Nation-Group uses some of it to replace the lost transport units. However, neither surface naval forces nor transport units are allowed to exceed the initial inventories. More details about the uses to which tactical land and sea forces, and strategic forces are put will be found in Section 4.

3.6.3 Equations in FORMAP

FORMAP performs all the following functions for each Nation-Group in turn, before proceeding to the next Nation-Group. Functions relating to strategic forces are only performed if the Nation-Group is also a strategic owner.

Determine funds available for procurement by deducting operating costs for the current quarter from the total military budget, B . In the case of strategic owners, R&D costs are also subtracted and procurement funds are divided between strategic and tactical forces. In summary form we have:

$$\begin{aligned} B &= B_{TP}, \text{ tactical forces procurement dollars.} \\ &+ B_{TO}, \text{ tactical forces operations and maintenance dollars.} \\ &+ B_R, \text{ R&D dollars.} \\ &+ B_{SP}, \text{ strategic forces procurement dollars.} \\ &+ B_{SO}, \text{ strategic forces operations and maintenance costs.} \end{aligned}$$

If the Nation-Group is not a strategic owner, the last three terms will be zero. The R&D budget is a percentage, p_r , of the military budget set by Subroutine BUDGET $B_R = p_r \cdot B$, where B_r refers to R&D dollars.

Likewise, the total spending for strategic forces is a percentage, p_s , of the military budget set by Subroutine BUDGET.

$$B_S = p_s \cdot B$$

Operating and maintenance costs are deducted from the total strategic forces budget to find the portion available for procurement. $B_{SP} = B_S - B_{SO}$

Figure 3-7 shows how the budget is divided if funds are inadequate to cover current operating and maintenance (O&M) costs. R&D and total strategic forces budgets are set up first and the excess is used to support the tactical forces. If operating costs exceed the budget for either force type, the simulation identifies the negative new procurement budget correctly as a lack of sufficient O&M dollars and reduces the inventory to reflect the loss by depreciation.

At the beginning of the game, four parameters, f_i , * are set equal to the desired procurement fraction for each of the four tactical land force types for each Nation-Group. On day zero, two additional parameters, f_5 and f_6 are set by FORMAP. The first is set equal to the cost to operate the initial naval surface forces, and the second stores the amount of transport units provided at the beginning of the game for each Nation-Group.

FORMAP next determines how the tactical forces budget is to be spent. The dollars to be spent on the four land types are set equal to the tactical force type times either the previously established procurement fraction, f_i , unit cost, C_i for the i -th weapon type, or the amount specified by Subroutine HIFT to meet military and political threat situations, n_i , whichever is greater.

$$P_i = \max\{n_i \text{ or } f_i\} \{C_i\} \text{ for } i = 1 \text{ to } 4$$

Where P_i is the amount to be spent by the Nation-Group for force type i , and C_i is the unit cost of that force type.

The TEMPER world allows for a maximum of 45 naval force deployments of either surface forces or SLBM submarines. All deployed forces of a given type are assumed to be identical in composition and each is characterized only by its size, the sea conflict region in which it is located, and the Nation-Group which owns it. Since there are 39 Nation-Groups and seven sea

*The subscript, i , corresponds to the list of tactical force types given in Section 3.6.1.

conflict regions, there could be as many as 546 different deployments, but the number can be limited to 45 to minimize Data Base storage space and still accommodate actual real world deployments. FORMAP scans the list of deployments, and computes the total surface forces deployed, the total number of SLBM submarines deployed, and the cost to operate the surface forces for each Nation-Group. Procurement for surface forces, P_5 , is then set equal to the positive difference between the initial O&M cost computed on day zero and the current O&M cost. In effect, the model does not permit a Nation-Group to increase its surface forces beyond the day zero inventory, but it can replace units lost in combat. As the size of the force decreases due to enemy action, O&M costs will decline from their initial value and so cause an increase in the procurement dollars from the initial value of zero.

If the Nation-Group is not a neutral,* the transport units procurement is computed. As with surface naval forces, the amount is not permitted to exceed the initial amount computed on day zero.

$$P_6 = (T_{6i} - T_{6c}) * C_6$$

where:

T_{6i} = initial amount of transport units.

T_{6c} = current amount of transport units.

where C_6 is the unit cost of transport units. FORMAP then computes the total tactical force procurement dollars, P , as the sum of the six amounts computed above.

$$P = \sum_{i=1}^6 P_i$$

$i = 1$

It should be understood that the amounts computed above are representative, and, as will be seen, the amount actually spent will be in proportion to the ratio of the previously computed amount, P_i , to the total amount, P .

*Neutrals do not own transport units, since they do not send military forces overseas.

If the strategic procurement budget is negative, the SLBM submarine force owned by the Nation-Group is adjusted downward.

$$\Delta S_4 = S_4 \left\{ \frac{B_{SP}}{B_{SO}} + D_S \right\}$$

where:

S_4 = the inventory of strategic force type 4, SLBM submarines occurs.

D_S = strategic force depreciation rate.

Since B_{SP}/B_{SO} is negative, S_4 is also negative.

FORMAP adjusts the surface naval force inventory. If the tactical force procurement budget, B_{TP} , was found to be positive, this quarter, additional naval surface ships and transport units are purchased. The surface naval force owned by the Nation-Group, and the size of the deployment is increased as follows:

$$\Delta T_5 = \frac{P_5}{P} \cdot \frac{B_{TP}}{C_5}$$

where:

T_5 is the inventory of tactical force type 5, surface naval forces.

The expression states that each deployment is increased in proportion to its relative size. The unit cost of surface naval forces is stored in a parameter, C_5 . The transport units inventory is similarly updated.

$$\Delta T_6 = \frac{P_6}{P} \cdot \frac{B_{TP}}{C_6}$$

where:

T_6 is the inventory of tactical force type 6, transport units.

If FORMAP has determined that the total tactical force budget is inadequate to cover O&M costs, it now depreciates each of the surface naval forces owned by the Nation-Group.

$$\Delta T_5 = T_5 \cdot \frac{B_{TP}}{B_{TO}} \cdot D_T$$

Where D_T is the inventory reduction factor for unmaintained tactical forces. The ratio of tactical procurement budget (when it is negative) to total tactical forces O&M costs, B_{TP}/B_{TO} , is the fraction of the force for which O&M funds were not available. This fraction is the depreciation factor. In other words, the model assumes that the full amount needed for O&M is spent on each force unit until no funds remain, and that the remaining forces then become worthless. Each force deployment is then reduced in number in proportion to the depreciation factor. Since the ratio is negative, ΔT_5 , will also be negative. O&M costs and depreciation are not computed for the sea transport.

SLBM submarine forces, S_4 , are likewise adjusted in response to the strategic procurement budget, B_{SP} . If it is positive, SLBM submarine deployments belonging to the Nation-Group are increased.

$$S_4 = \frac{P_{S4} \cdot B_{SP}}{C_{S4}}$$

The fraction of the strategic procurement budget spent on SLBM submarines, P_{S4} , is fixed for each Nation-Group at the beginning of the game. The unit cost for SLBM, C_{S4} , is also set at the beginning of the game, but is the same for all Nation-Groups.

The O&M costs for the naval surface forces and transport units, and for the SLBM submarines is computed for the updated inventories for use the next time FORMAP is operated.

FORMAP then updates the inventories of the four tactical land forces in a similar fashion. If the tactical procurement budget is positive, then:

$$\Delta T_i = \frac{P_i}{P} \cdot \frac{B_{TP}}{C_i} \quad \text{for } i = 1 \text{ to } 4$$

where ΔT_i is the inventory increase factor and C_i is the unit cost of the i -th tactical land force type.

If the tactical force procurement budget is negative, the tactical land force inventories are proportionately decreased as the surface naval forces were:

$$\Delta T_i = \frac{B_{TP}}{B_{TO}} \cdot D_T \quad \text{for } i = 1 \text{ to } 4$$

The O&M costs for the revised force inventories are added to the surface naval forces O&M costs to obtain a new value for total O&M costs, which will be used by FORMAP later to compute exogenous force depreciation, and at the end of the next quarter to compute the tactical O&M bill for the Nation-Group.

In the same way procurement or depreciation of each of the land strategic forces owned by the Nation-Group is next computed.* If the strategic budget is positive, then:

$\Delta S_j = B_{sp} \cdot P_{Sj} / C_{Sj}$ for $j = 1$ to 3 corresponding to the first three strategic force types listed in Section 3.6.1, if the force is home based. If it is not at home, no additions are made to it.

If the strategic procurement budget is negative, the force is depreciated regardless of its location.

$$\Delta S_j = \frac{B_{SD}}{B_{SO}} \cdot S_j \cdot D_S$$

The O&M cost of the revised inventory of land strategic forces is added to the O&M cost for the SLBM submarines computed above to obtain the total strategic force O&M cost for use by FORMAP at the end of the next quarter.

FORMAP then returns to the first step (page 88), and repeats the computations for each Nation-Group, until all have been considered.

The final function of FORMAP is to update the operating costs of exogenous tactical land forces. It does this by examining each entry on the list of exogenous forces. ** For each entry it checks the sign of the tactical procurement budget of the owner. If the budget is negative, the force is depreciated in the same way as other forces. If the budget is positive, the force is not increased. The C&M cost is computed for each exogenous force, and is added to the O&M cost of the owner Nation-Group and deducted from the O&M cost of the host Nation-Group. This step is necessary because the

*The TEMPER model allows for a total of 20 strategic forces throughout the world, each of which is characterized by its size, its type, and its location.

**Exogenous forces are characterized by size, force type, owner, current location, and destination.

O&M cost for a given Nation-Group is initially computed for all tactical forces within the Nation-Group. The model assumes that each Nation-Group will pay the O&M costs only for its own forces, but will do so when they have been deployed overseas. When FORMAP has completed its update of the exogenous forces, it returns control to Subroutine ECON.

4.0 War Submodel (WAR)

The War Submodel simulates tactical war between Nation-Groups within the Land and Naval Conflict Regions of TEMPER. Directed land conflict can occur only between Nation-Groups belonging to the same Land Conflict Region. Allies who have given military support to a Nation-Group engaged in war are involved in that war to the extent that their forces are used in combat. Losses inflicted and sustained by these allies are proportional to those of the Nation-Group they are supporting.

Naval conflict occurs when the navies of combatants of opposing blocs involved in land conflict meet in one of the seven naval conflict regions. In this case, the combatants are considered to include the opposing Nation-Groups in the conflict region where the war is being fought and the allies who are supporting them.

The War Submodel reacts to decisions regarding escalation and de-escalation from the Decision Maker Submodel, and performs in a military environment established by the Logistics subroutines and variables of the War Submodel. The principal outputs consist of force and economic losses and the exchange of occupied or dominated land area. Land exchange (advance/retreat) is computed as a function of the difference in force levels.

The War Control Subroutine of TEMPER controls the execution of the seven subroutines which make up the War Submodel. These are both battle and logistic subroutines. There are three battle subroutines. These are LIWAR, FIGHT, and NAVFYT. LIWAR performs most of the military computations, including preliminary computations needed in the FIGHT subroutine. The actual output for land conflict, which occurs when desired military operations is above the war threshold, is computed in FIGHT and that for naval conflict in NAVFYT.

The Logistics subroutines (NAVLOG, SHIFT, REMOVE, and STAGER) provide and update complete records of each Nation-Group's land and naval forces. Land forces are tactical air wings, "ROAD" divisions

(combined infantry-artillery', paramilitary groups, and nuclear army divisions. Exogenous forces, those deployed to an ally, and total forces deployed to any Nation-Group are calculated. There are no records kept of forces supplied to Neutrals. These are given to a neutral and become a part of the neutral owned force. There are, therefore, no exogenous forces in neutral territory although a record is kept of offers made to neutrals. Naval forces in TEMPER do not include strategic submarines which are assumed not to participate in logistic or tactical operations.

The Logistics subroutines determine what forces to ship (by sea) from where-to-where, on the basis of force needs and ally permission. The LIANCE and XLIANCE Subroutines provide a consignment schedule indicating how much each ally is willing to ship to each other ally, but not which type of force is the least effective in its homeland or point of loading in the case of exogenous forces. The SHIFT Subroutine decides which type of force on a cost-effectiveness basis can be used best by the receiving ally and tries to find that force type in the forces available for shipment. A record of unsatisfied needs is maintained for procurement purposes. The STAGER Subroutine updates the force records as a result of shipments. It is also called upon by the FIGHT Subroutine to update the records when force losses occur. The NAVLOG routine moves naval force according to desired naval operations.

4.1 Subroutine Limited War Control (LIWAR)

4.1.1 General Description of LIWAR

The LIWAR Subroutine performs a number of bookkeeping functions for the TEMPER world prior to determining the outcome of a week's battle. These functions include forcing nations to go to battle if their opponents are continuing activity at the war level, stopping the simulation when the number of wars becomes excessive, assigning control numbers to new wars, and returning prisoners when a war has been terminated.

LIWAR then selects the front lines for any new wars, each week establishes the terrain type for each war then in progress, determines the basic counterforce effectiveness for all countries at war, sets some random variables to account for campaign variations in wars, and measures the counterforce utility for forces at war or enroute to a war.

Finally, the exogenous force counterforce utility is measured and a cost-effectiveness computation is made. Table 4-1 shows the order of execution of the functions of LIWAR.

TABLE 4-1

LIWAR FUNCTIONS

- a. Assign numbers to new wars, stop simulation if number of wars become excessive (exceeds ten), return POW's in cases of Terminated Wars.
- b. Establish front lines for new wars and the terrain type each week for all wars in progress.
- c. Establish force effectiveness tables for all Nation Groups at war.
- d. Set random variables for campaigns.
- e. Measure counterforce utility for forces at war or enroute to a war.
- f. Measure counterforce utility for exogenous forces.
- g. Perform cost effectiveness computation.

4.1.2 Detailed Description of LIWAR

The LIWAR subroutine is called to perform the bookkeeping functions as described in 4.1.1. After these functions are performed, the subroutine performs the remaining functions of LIWAR which can be grouped into the following three categories:

- a. War control
- b. Determination of conditions of war.
- c. Computations of relative force effectiveness.

The LIWAR Subroutine first performs the war control functions. If any bloc in a conflict region is directing military operations at a level above the war threshold the subroutine determines whether the opponents level of military operations is at least at the threshold. If not, the value is set to the threshold level. The level of military operations is measured on a scale from 0 - 10. Six is the war threshold. The level of this variable may be affected by operations in Subroutines ACBARG, CDALC, and FIGHT as well as LIWAR. If a new war has broken out, a check is made to see if there are already ten wars. If so, the model is stopped, and the game is terminated. Otherwise, a control number is assigned to the new war. If a war has just been terminated, then 90 percent of the prisoners of war are returned to their homeland.

The conditions of war include determining terrain type, basic effectiveness, and selecting the relative campaign effectiveness of opponents. Terrain type is selected each week for all wars in progress on a weighted random basis. There are three terrain types which are described in terms of the freedom of armor to move. The terrain is expressed in terms of a front line location variable ranging from 0 - 1. The land is arranged from 0 - 1 in descending order of compatibility with operations of armor, and the position along this is measured by the front location. This front location is selected for a new war when it starts, and is changed by advances and retreats of the armies. Since, for new wars, the starting front is selected by a

uniformly distributed random number, the probability that the war starts in a terrain of a given type is proportional to the percentage of that type terrain in the conflict region. (See Equation 1, Section 4.1.3).

The basic counterforce utility of a weapon type is a function, of the firepower degradation of the weapon, the force vulnerability of all possible tactical target types, and the basic firepower effectiveness of the weapon against each of the target types.

Force vulnerability (and similarly firepower degradation) are computed differently for peacetime and for wartime. In peacetime, and on day zero, the measure of vulnerability (1/survivability for each terrain type), weighted across percent of each terrain type in the conflict region is taken (see Equation 2, Section 4.1.3). In wartime, the terrain type is known, so that specific measures may be made for fighting in that terrain by assuming vulnerability (1/survivability) and degradation figures for that type terrain.

Basic firepower effectiveness is an input parameter representing an unmodified effectiveness for each force type against all possible tactical targets.

The overall value for the effectiveness of a force type in a particular terrain (or in the averaged terrain during peacetime) is called the basic counterforce utility. In TEMPER it is assumed that this value will be the same for each nation's forces in the same conflict region. It is determined by adding the value for each of the four target types which results from the product of the force vulnerability of the force type being fired upon, and the basic firepower effectiveness for the weapon against that target. This sum is then multiplied by the firepower degradation values for the attacking weapon. Thus, the basic counterforce utility measure incorporates the general effectiveness of the weapon, the basic vulnerability of each of the target types to the weapon, and the adjusted vulnerability of the target in that terrain. (See Equation 3, Section 4.1.2.)

A random campaign variable is selected to represent the various elements of the campaign which are highly unpredictable or too detailed to warrant treatment in the TEMPER model. This number is used to enhance or degrade the counterforce utility of forces at war. In this case, a random number is selected which results in a number between -2σ and $+2\sigma$ as follows:

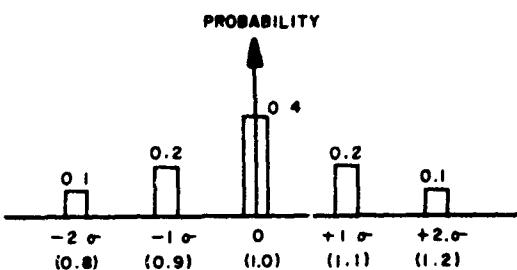


Figure 4-1 Range of Random Campaign Variable

and where σ is the standard deviation for variance of force effectiveness for each bloc. This deviation is selected for each bloc in the preparation of the Data Base. In the current Data Base it is set to 0.1 for each of the three blocs. (See Equation 4 in Section 4.1.3.) The range of the random campaign variable is therefore from 0.8 to 1.2, with probabilities as shown at the top of each bar in Figure 4-1. This computation is made once at the beginning of a war for each belligerent.

Up to this point, TEMPER has computed the conditions for war including terrain and basic counterforce utility without regard to side, and the effects of chance on the campaign for each side. Now TEMPER, determines the relative force effectiveness between belligerents and for non-combatants whose force sizes have changed (shipped or procured).

The total counterforce utility of a nation is computed in two steps. First the counterforce utility for each of the Nation Groups of interest is computed. Then the value is increased if these are nuclear army divisions and the

PAL key (Permissive Action Link) is on, i. e., the nuclear weapons have been released for use. Otherwise, the nuclear army divisions are presumed to have the same effectiveness as ROAD divisions.

To determine the counterforce utility for a Nation Group, the utility of each of the four types of forces is summed. The utility figure for each force type is determined by multiplying the basic utility of that force type (see 4. 1. 2 above) by the number of units of that force type in the nation. The summed figure is then modified by the random campaign variable where the nation is at war. (See Equation 5, Section 4. 1. 3.) If there are nuclear army divisions and the nuclear weapons have been released, the total utility figure is increased by adding the product of an enhancement factor (0. 3 for the current Data Base) and the number of nuclear army divisions in the country. (See Equation 6, Section 4. 1. 3) This enhancement factor represents the increased counterforce utility per nuclear army division which results from releasing their tactical nuclear weapons for use. Without this enhancement, the nuclear army division is assumed to have the same utility as a ROAD division.

Exogenous counterforce utility is a portion of the total utility computed for total counterforce utility above and represents that portion contributed by exogenous forces in the Nation Group. It is computed by going to a table of deployments and for each entry computing the counterforce utility in exactly the same way as described above for the total value. The exogenous force utility function sums across the force types for each location-owner combination, making available a list of exogenous counterforce utility values showing the owner, the location, and the value of the forces.

Cost-Effectiveness computations are made (see Equation 7 in Section 4. 1. 3) by dividing the basic effectiveness of that type force in the Conflict Region by the quarterly cost of operating a unit of that force. This figure is not used by the simulation, but is printed out for examination by the analyst.

4.1.3 Equations in LIWAR

1. If war front number \leq % terrain type 1 - then use type 1.
If war front number $>$ % terrain type 1 + terrain type 2 - then use type 3.
All others use type 2.
2. Force Vulnerability = $1/\text{Survivability of weapon in terrain Type 1}$
 \times % terrain
Type 1 + $1/\text{Survivability of weapon in type 2 terrain}$ \times % terrain
Type 2 + $1/\text{Survivability of weapon in type 3 terrain}$ \times % terrain
Type 3
Firepower degradation is determined by substituting, for the value $1/\text{Survivability parameter}$ of the weapon in the terrain type, the value of the degradation parameter in each type terrain.
3. Basic counterforce utility = $\frac{(\text{firepower degradation}) \times \sum \text{ (force vulnerability} \times \text{ basic firepower effectiveness)}}{\text{all force types}}$
4. Random campaign variable = $1 + (\text{Standard deviation}) \times (\pm \text{ random variable})$
5. Counterforce utility = random campaign variable \times sum for all force types of (basic utility for force type \times amount of force).
6. Counterforce utility (if level Mil. Ops ≥ 8) =
Eq 5. + (Enhancement factor \times No. of
Nuc. Army Divisions)
7. Cost effectiveness = Basic counterforce utility per unit of force/quarterly operating cost for the force type.

4.2 Subroutine Fight the Land Battle (FIGHT)

4.2.1 General Description of FIGHT

The FIGHT Subroutine computes the outcome of tactical conflict on land. In this subroutine the advance (as a fraction of total area in the region), the new location of the front, and various losses are computed.

In performing these computations the following operations occur:

1. Battle Operations

- a. Computation of advance as a fraction of the total land of the Conflict Region.
- b. Determine new battlefield location.
- c. Identify defender to give it a defense advantage.

2. Loss Computations

- a. Compute losses to force types
- b. Compute other losses resulting from war including pressures of war, land, capital wealth, and work force.

4.2.2 Detailed Description of FIGHT

This subroutine examines each war separately and determines the outcome of the week's war activity. If one Nation-Group is involved in two wars, each will be treated separately each week, and in the order of assigned war number. If a war results in the complete occupation of the nation, then at the end of that week's operations the model would require that the Data Base be reaggregated to remove the political, economic, and military autonomy of the occupied country. The fight computations may be considered as a two step process. First, the battle operations are defined (advance, battlefield operations and defensive advantage). Then the effects of these operations are computed (loss by force type, land held, prisoners of war, capital wealth, and work force).

The advance experienced in a week's battle operations is basically a function of the relative counterforce utilities available to the opponents.

This counterforce utility changes over time during the war as a result of changes of force levels and mix (e. g., losses, and shipments of aid), and changes in the terrain over which the battles are fought (the war front).

The current activity rate for the war is also used to compute advance. This activity rate represents a momentum of the war. It is a smoothed value for previous histories of advance. This is done by taking the average of the previous week's momentum and the actual advance in square miles. (See Equation 1, Section 4.2.3.) Thus, the most recent advances have more influence than the earlier advances. The value is both scaled and bounded with a maximum and minimum value.

While the values for counterforce utility change each week, the full effect may not be immediately felt. As a counterforce ratio approaches one, the advance will dampen. When the ratio advantage shifts to the other side, and grows in its favor, the momentum will pick up again in the opposite direction. Only if there is a sudden reversal in counterforce ratio representing a shift of significant proportion will the momentum stay high, but the direction of the advance reverses. This could result from large shipments received from an ally or sudden upsetting of the balance, resulting from a change in battlefield terrain. The advance (see Equation 2 in Section 4.2.3) after computation is bound so as not to exceed the amount of land available to be occupied.

As advances are made, there may be a change in the terrain on which the battle is being fought. In TEMPER the starting front line position is selected on a random basis during the first week of war in the LIWAR portion of the model. After the selection the change in terrain is a function of how much advance is made, and the distribution (%) of the three terrain types. The three types of terrain are distributed in series along the war front variable.

Each week the front is advanced across the war front variable in the amount of the advance. If an advancing nation maintains its counterforce advantage, then it may advance until the other Nation-Group is completely

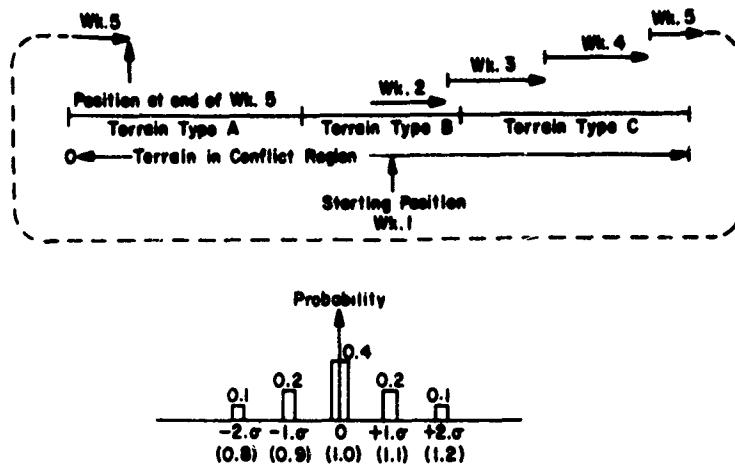


Figure 4-2 Advances and Changing Terrain Types

occupied. In this case, the front position will have progressed along the variable a distance equivalent to the fraction of land held by the losing nation in the region at the beginning of the war. When the end of the variable is reached, the advance proceeds to the 0 setting and continues. Since during TEMPER time forces in Conflict Regions are shifted toward a more optimal distribution, there would be a tendency over time for the mix of forces held by opponents to become more and more similar. As this occurs, the effect of shifts in terrain may become less important.

The defense advantage is determined before the model is used by setting parameters which result in an enhanced survivability for the defending force. This reduces their vulnerability.

The FIGHT Subroutine computes losses (and gains) data for other sections of the simulation.

The force losses by force type are a function of various elements which may be discussed as two factors; the target factor (for the force where losses are being computed) and the firing force factor.

The target factor is made up of the survivability parameter for the force type being fired upon, the terrain where the war is being fought, the level of war activity, the posture of the target force (advancing or withdrawing),

and the size of the force being attacked. In the TEMPER model, the vulnerability table is set at the beginning of the analysis as a parameter input to the Data Base. The more a terrain type reduces a force's mobility, the less its survivability. The more cover the terrain provides the force without hindering it, the more the survivability. The size of the target force is the total of all forces of that type located in the Nation-Group suffering the loss. The level of war activity is the activity rate described above. A posture of defense results in cutting the losses experienced by the withdrawing force, compared with an advancing one. The defense advantage constant is set in as a parameter at the beginning of the analysis. In the present Data Base a defending force has two to one advantages over the advancing force. The vulnerability of the force equals the size of the force modified by the other element of the computation. See Equation 3. How much of this net vulnerable force is destroyed, depends on the firing force factor.

The firing force factor may be considered as a kill potential against the net vulnerable force. This kill potential is modified by the random factor which determines if a campaign is more or less effective for the attacker, degradation of firepower by terrain, basic firepower effectiveness of the force type against the target, and the size of the target force deployed in the attacking or firing country. The random campaign factor is computed in LIWAR for each participant. The degradation of firepower by terrain is put in as a parameter at the beginning of the game. For all force types except paramilitary, the firepower is degraded as the front lines move into more and more difficult terrain. The basic firepower effectiveness of a force type against another, is also set as an input parameter. See Equation 4 in Section 4. 2. 3 for the computation of kill potential. The kill potential for the four types is summed to get the full value for the attacking force and the total loss of each force type attacked is shown in Equation 5 (Section 4. 2. 3).

The prisoner of war loss by a nation group each week is a function of the number of soldiers in each force type. See Equation 6 in Section 4. 2. 3.

The dollar value, or cash lost is determined by multiplying the amount of each force type lost by the procurement cost of that force type.

See Equation 7 in Section 4. 2. 3.

The new land figure is computed by reducing or increasing the last amount by the amount of the advance. See Equation 8 in Section 4. 2. 3.

Similiarly, the capital wealth of a nation-group is reduced in proportion to the cash lost.

The work force of the nation-group is reduced by the number of prisoners of war taken.

Finally, if all land in a nation-group is occupied, preparations are made to stop the analysis by providing for reduction in the aggressiveness of the winner.

4. 2. 3 Equations in FIGHT

1. Momentum factor* = $\frac{K. \text{ Last week's momentum} + \text{Last week's advance in Sq. Mi.}}{2}$

where K = a constant and where the momentum factor is bound by a minimum value.

* This value is in sq. miles.

2. Advance = $\frac{\text{Momentum}}{\text{Size of Region}} \times \frac{\text{CFA} - \text{CFB}}{\sqrt{3/1 + \text{CFA} + \text{CFB}}}$

where CFA, and CFB are the force utilities of A and B respectively.

3. Net Vulnerable Force = $\frac{K \times \text{Activity} \times \text{Force Size}}{\text{Survivability}}$

where K = constant giving defending (retreating)* forces an advantage.

4. Kill Potential* = Random Campaigning Factor x degradation by terrain
x basic effectiveness of the force type x number of force units.

* Defending here does not refer to the nation-group first attacked. Defending is used in the sense of the nation retreating or withdrawing, that is presumed to have an advantage because it can exercise some choice of what to defend and what not to defend.

*In the case of Nuclear Army Divisions, this figure is reduced by 70% to simulate loss of effectiveness when the nuclear weapons cannot be used, even though they must be carried along.

5. Loss = Net Vulnerable Force x Summed Kill Potential for attacking forces.
6. Prisoners of War Lost = Sum for all force types of (Loss for each force type x K).

Where K = a constant collateral manpower associated with the force type. Ten percent of these will be presumed killed when the war is terminated and POW's are returned home.

7. CASH LOST = Amount of Force Lost x Cost to procure one unit of that type.
8. AMT OF LAND = OLD AMT HELD + Advance

Where + indicates land gained (Advance)
- indicates land lost (Retreat).

4.3 Subroutine Staging (STAGER)

4.3.1 General Description of STAGER

The STAGER Subroutine is a bookkeeping routine which updates the total tactical force levels, the exogenous tactical force levels, the corresponding counterforce arrays, and computes force losses in limited wars.

The values (amounts and utility units) used by STAGER are computed in LIWAR and FIGHT and supplied when STAGER is called.

The steps for losses are as follows:

- a. For each loss find the owners of forces in the Nation-Group suffering the loss. Reduce these owners exogenous CFU records by the percent the loss represents in the total CFU at that location (See equation 1 in Section 4.3.2).
- b. For each loss find the forces of the type last deployed to the Nation-Group suffering the loss, and reduce each record of deployed force by the percent the loss represents of the total of that type at that location. (See equation 2 in Section 4.3.2).
- c. Reduce both total CFU and total units of the type lost, recorded at the Nation-Group suffering the loss, by an amount equivalent to the percent reductions used for exogenous CFU and exogenous force above.

In computing losses TEMPER assumes that for any loss the exogenous owners and the Nation-Group where losses are incurred will each suffer in the same proportion. That is losses will be evenly distributed over all CFU's and forces of the type lost which are at that location.

The steps for loading and unloading adjustments are as follows:

- a. Adjust total deployed force in Nation-Group involved by the shipment amount (add for receipt, subtract for shipment).
- b. Adjust total CFU in Nation-Group involved by the shipment amount (add for receipt, subtract for shipment).
- c. Adjust exogenous force table by shipment amount.
- d. Adjust exogenous CFU table by shipment amount.

Since the functions are adding and subtracting only, no detailed discussion of the subroutine is needed. Two important elements of the transaction, however, are important.

When the entry involves the receipt of a shipment, the recipient is examined to determine if it is a Neutral. If so, no record is kept of exogenous nature of force. This in effect makes gifts of all military shipments to Neutrals. They become the property of the Neutral and are not subject to recall. Since Neutrals may not ship forces, the forces stay there unless the Neutral cannot maintain their cost of operation and their size decreases.

When an incoming entry for exogenous forces is less than five percent of the total of that type force in a Nation-Group, then it is accepted as a gift and added to indigenous forces. If an exogenous force is withdrawn and results in an exogenous force of less than five percent of total force for the type involved to the Nation-Group deployed by the owner, then the remaining exogenous forces for that entry and the corresponding force utility points are transferred to the ownership of the Nation-Group where they are located. If the total force utility of a nation's exogenous forces in a Nation-Group is reduced to less than five percent of the total utility for that country, then those exogenous utilities are transferred to the ownership of the Nation-Group where they are located.

4.3.2 Equation in STAGER

$$1. \text{ Deployed CFU}_{\text{new}} = \text{deployed CFU}_{\text{old}} - \text{deployed CFU}_{\text{old}} \times \text{lost CFU/Total CFU}$$

where
deployed CFU = records of exogenous CFU in Nation-Group suffering loss
lost CFU = CFU's represented by loss
Total CFU = total value in CFU of force located in Nation-Group suffering loss.

$$2. \text{ Deployed Force}_{\text{new}} = \text{Deployed Force}_{\text{old}} - \text{Deployed Force}_{\text{old}} \times \text{lost Force / Total Force}$$

where
deployed Force = records of exogenous force in Nation-Group suffering loss
lost Force = Amount of loss in units lost
Total Force = Total force of that type located in Nation-Group suffering loss.

4.4 Subroutine Naval Fight (NAVFYT)

4.4.1 General Description of Subroutine NAVFYT

As its name implies, Subroutine NAVFYT is the naval counterpart of Subroutine FIGHT. Its task is to compute the expected losses resulting from naval conflict between the two opponents and all other participating Nation-Groups engaged in fighting each of the ten possible wars. Participating Nation-Groups are those which have supplied military forces to either of the opponents. Naval conflict occurs in the seven sea conflict regions of the TEMPER world. These are described in more detail in Section 4.7.

Naval forces include three types: transport units, SLBM submarines, and surface naval forces. The latter category includes all naval forces not included in the first two categories. SLBM submarines include only those which are strategically armed, i.e., conventional subs are included as surface naval force rather than SLBM subs.

The only force type which can inflict casualties on other naval forces is the surface naval force. Transport units, SLBM subs, and surface naval force can all be destroyed. In general, naval losses are proportional to the product of the number of attacking vessels and the number of target vessels in a given sea, i.e., proportional to the probability that the two forces will meet.

Conflict can break out in any of the seven seas where "opponent" forces meet. Special consideration is given to transport units destined for the conflict region at war. The probability that the unit will be destroyed is proportional to the number of days it must travel before reaching its destination and to the size of the unit. This probability is computed and then compared with a random number. If the probability is greater than the number, the transport unit and the shipment are destroyed.

The NAVFYT Subroutine has two major functions as shown in Figure 4-3 . The first is to identify the opponents engaged in a war and the second is to compute the surface naval forces and transport units losses these Nation-Groups will incur. Each possible war is considered in turn.

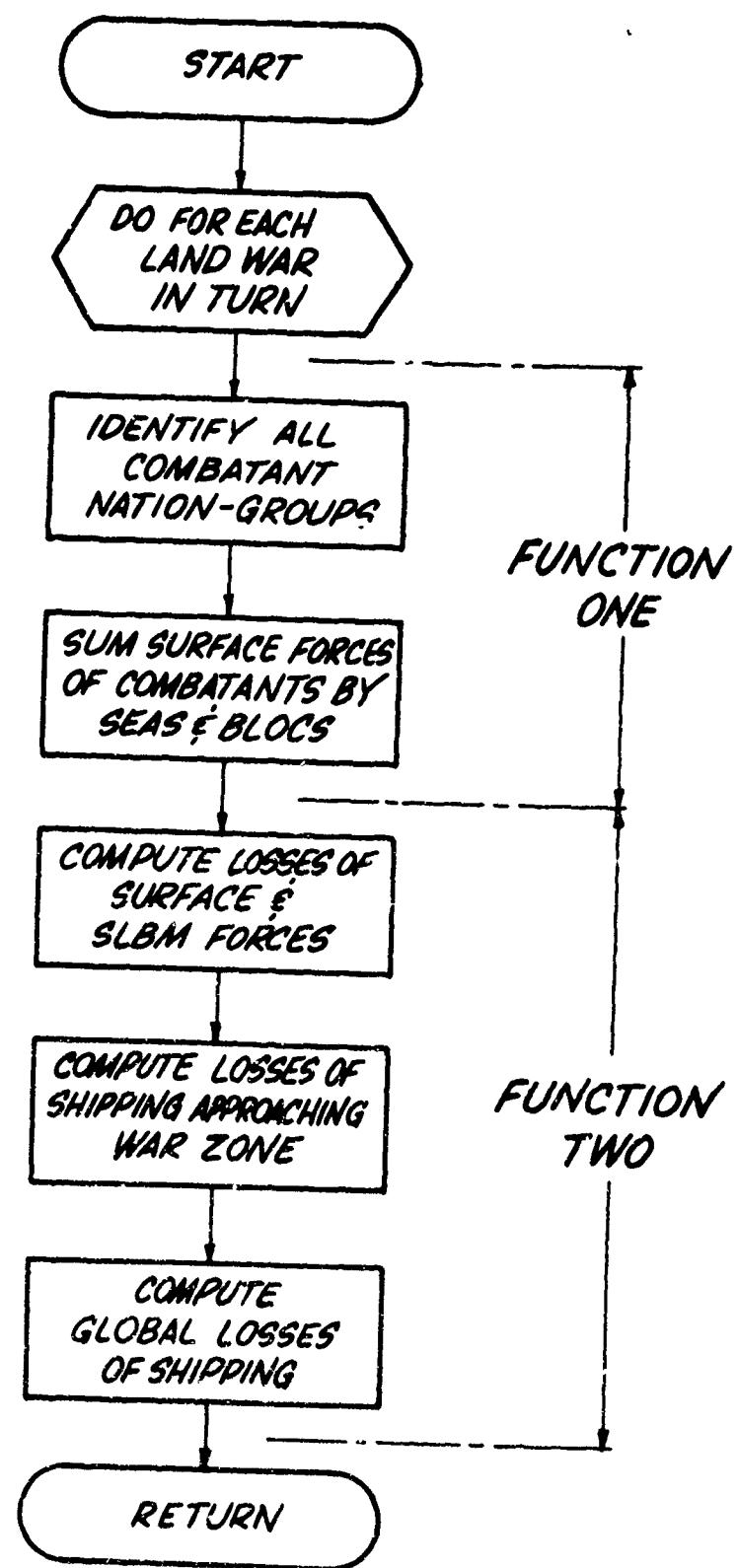


Figure 4-3 Simplified Flow Diagram of Subroutine NAVFYT

4.4.2 Detailed Description of Subroutine NAVFYT

The first function of NAVFYT is to determine the participants in an existing war by identifying the Nation-Groups with military forces located in the Conflict Region at war. This is done by identifying those allies from whom the two direct opponents have received military aid. These are the only Nation-Groups whose forces are considered in the loss equations.

Then NAVFYT determines the extent of losses. Three loss equations are used to compute naval force losses.

The first of these computes losses to SLBM subs (IN = 1) and surface naval force (IN = 2).

The equation is:

$$\text{LOSS}_{IN, A} = K_{IN} \times \{ \text{Force}_{IN, A} \} \times \{ \Sigma \text{Opponent Surface Navy Force} \}$$

where A is the Nation-Group for whom losses are being figured. The coefficient K measures the percentage loss which a single Navy force unit inflicts on subs (IN = 1) and on Navy (IN = 2) per week of war. This loss computation is made each week of war for the forces of the combatants in each of the sea regions.

The second equation is used to compute the probability that a transport unit destined for the conflict region at war is destroyed. A transport unit is the simulation of cargo ships, or more directly the cargo carrying capacity they represent. In the sections dealing with military force logistics, the reader will find references to shipping channels. The term is used to refer to the record of each shipment, and is not to be confused with transport unit. A check is made to see that the force is within 7 days of its destination. If so, the following computation is made.

$$\text{PROB} = K_3 \times \left(\frac{\text{Number of days till arrival}}{7} \right)^x \left(\text{Size of Transport Unit} \right) \times \Sigma \text{Opponent Surface Navy Force}$$

where K_3 is a scaling coefficient and Opponent Surface Navy Force is the average deployment* for the seas contiguous to the destination region. A random number is selected. If PROB is greater than this number, the transport unit and the military force aboard are destroyed.

The third equation is used to compute the global attrition of the shipping units of each participant. The equation is:

$$\text{Loss}_A = \left(\text{Shipping Units of Nation-Group A in U} \right) \times K_5 \times \Sigma \text{ Opponent Surface Navy Force}$$

where K_5 is a scaling coefficient and A is the Nation-Group for whom losses are being figured. Opponent Surface Navy Force is the total of all naval forces owned by opponent bloc combatant.

4.4.3 Equations in NAVFYT

1. Naval Force losses other than Transport Units

$$L_{ia} = K_i \left\{ F_{ia} \left\{ \left\{ \Sigma F_a \right\} \right\} \right\}$$

where L_{ia} = loss of i-th force type of Nation-Group a.

K_i = a constant.

F_{ia} = the size of the i-th force belonging to a.

F_o = the size of each opponent force in the sea conflict region in which the force of a is located.

Note: i = 1 for SLBM subs
= 2 for surface forces.

2. Losses of Transport Units in the Combat Zone

$$P_a = K_3 \left(\frac{D}{T} \right) \left(T_a \right) \left(\Sigma F_{oa} \right)$$

* the average force is found by dividing the total force in the seas contiguous to the conflict region of the war, by the number of contiguous sea.

where P_a = the probability that the transport unit belonging to Nation-Group a will be lost.

K_3 = a constant.

D = days remaining for the transport unit to arrive.

T_a = the size of the transport unit

F_{oa} = the average surface force of each opponent in the sea region in which the transport unit is located. It is F_o divided by the number of seas adjacent to the land combat region.

If P_a is greater than a random number, the transport unit is assumed to have been destroyed. It is subtracted from both the total transport inventory and the in use inventory of the owner Nation-Group. The military force shipped is also deducted from the inventory.

3. Global losses of Transport Units

$$L_a = K_5 \left\{ \sum T_a \right\} \left\{ \sum F_o \right\}$$

where L_a = the losses in all seven seas of Nation-Group a.

T_a = Each transport unit of a which is at sea.

F_o = Each surface naval force of the opponent Nation-Groups.

K_5 = a constant.

4.5 Subroutine Shift of Military Forces (SHIFT)

4.5.1 General Description of SHIFT

SHIFT is a part of the War Submodel of TEMPER. Its basic function is to redistribute excess military force among allies as a form of alliance aid and then distribute to needy neutrals the remaining surplus. To carry out its function, SHIFT first computes the unmet counterforce utility units for each Nation-Group in each bloc. Then the attempt is made to redistribute the surplus of each non-neutral bloc. In the current Data Base, this order is first West then East.

For the bloc for whom aid is being considered, the most needy Nation-Group is determined. Then the most cost-effective force for that Nation-Group is selected, offers for aid are scanned to see if any of that force type are available, and, if so, the closest available force is shipped. The process is repeated using other suppliers and less cost-effective forces if necessary, until either the need is met; offers are depleted, or offerors have no more shipping capacity. Then, the next most needy Nation-Group tries for aid. The process is repeated until all Nation-Groups in the bloc have had a try. Then, the next bloc (or Neutral) is considered for aid. This process is repeated until all Nation-Groups of the different blocs have had their try or world shipping channels are full, at which time residual requirements are computed for each bloc.

The functions of SHIFT are summarized in Table 4-2.

TABLE 4-2
FUNCTIONS OF SHIFT

- a. Determine the net desired counterforce utility.
- b. Determine Force-Effectiveness, Cost, and most needy Nation-Group in bloc to receive aid.
- c. Select best offer of aid and ship.
- d. Determine remaining needs in the bloc.

4.5.2 Detailed Description of SHIFT

First, a computation is made of the net (unmet) desired level of counterforce utility. Then the attempts are made to redistribute surplus in the following order:

Meet Western Bloc alliance needs

Allow West to meet Neutral needs

Meet Eastern Bloc alliance needs

Allow East to meet Neutral needs

This order is a function of the way in which the Data Base is aggregated, and can be changed.

Military force and the desire to have it are measured in the TEMPER model in terms of counterforce utility. While a Nation-Group's forces are of different types, such as tactical air wings or ROAD divisions, the common measure is their usefulness against targets in the region in which they are to be used. This is determined in LIWAR.

The desire for force will depend on the force levels required to make viable the military operations directed against an opponent, and the forces required to maintain order at home. (See equation 1, section 4.5.3).

The level of force required to make viable the military operations directed at an opponent is dependent on the size of the opponent's force, and the level of operations directed at the opponent. The higher the level of military operation, the greater the desire for advantage. A constant is set into equation 1 resulting from a desire for a 1:1 ratio at the war threshold. Below the level of war less than 1:1 is desired, but as a war increases in military operations level, greater and greater superiority is sought. Figure 4-4 shows how the desired counterforce ratio increases as a function of an increased level of military operations. This ratio is applied against the perceived counterforce level of the opponent to determine the desire resulting from operations against that opponent. The perceived level of opponent CFU is increased by 0.1 CFU to represent a latent threat regardless of the size of the opponent forces. Thus a Nation-Group will always contribute in at least a small way to the desire of a neighboring Nation-Group for CFU.

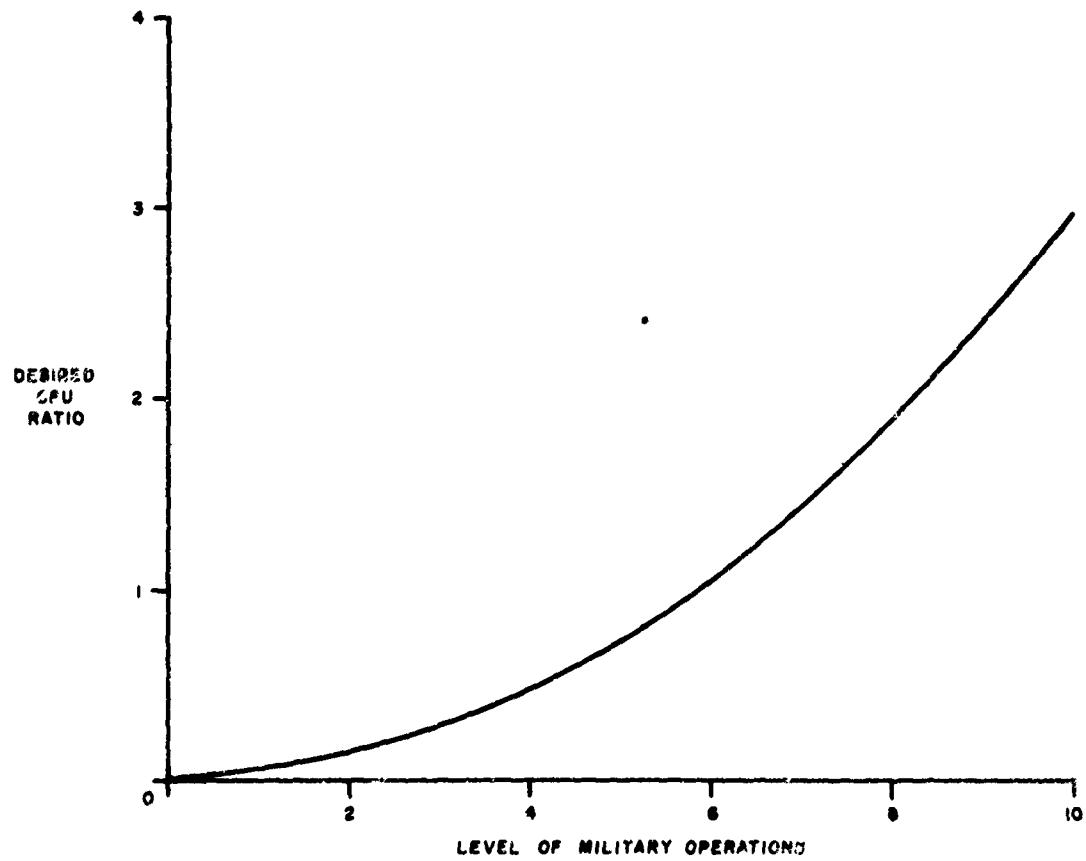


Figure 4-4 Desired CFU Against a Single Opponent versus Level of Military Operations

The value resulting from both neighboring Nation-Groups is added together with the forces required to keep internal order at home. This is assumed to vary from country to country, but in general is believed to be higher in Eastern bloc nations than in Western bloc nations.

4.5.3 Distribution of Surplus Force

Surplus forces are distributed among alliances and to neutrals on the basis of offers of aid made by Subroutine REMOVE, Section 4.6.

In order to make reasonable selections from among aid offers, the cost-effectiveness of the forces offered in the region where they are to be used is determined.

Effectiveness of a force type is a function of the basic counterforce utility. In TEMPER this is different for each force type and unique to the region of location. In a conflict region, however, all Nation-Groups are assumed to have forces of equal effectiveness per unit (see Equation 2, Section 4.5.3). If a nation is at war, then the basis of effectiveness of the force type is enhanced or degraded by a random campaign factor which is also set by LIWAR. This random campaign factor may result in a relative advantage for one side over the other simulating the effects of unpredictable elements of the campaign or elements detailed to allow inclusion in TEMPER.

The operating (O&M) cost for a unit of force is assumed in TEMPER to be the same regardless of location or level of military operations (whether it is in war or peace). It does vary however as a function of force type. Shipping cost per transport unit is also assumed to be a constant. Since a transport unit will accommodate different amounts of force units depending on type, a differential shipping cost by force type is available. In determining the cost effectiveness of a unit of a given force type, TEMPER uses the basic counterforce utility for the type in the conflict region where it is to be used (if there is a war modifier this value is to account for the bias in the campaign), the operating cost and the shipping cost. (See Equation 3, Section 4.5.3;) The result is that in a given conflict region the cost effectiveness of a given force type will be the same for all Nation-Groups.

Since, over time, forces are shipped on the basis of transferring forces from where they will be least cost effective to where they will be most cost effective, there will be a tendency to move, in a single Conflict Region, toward a similar mix of forces in each of the Nation-Groups located there.

After computing the effectiveness and the cost for each type of force, REMOVE determines which Nation-Group is in the most need of force. An attempt will be made to meet the total needs of the most needy Nation-Group in the bloc first. After these needs are met, or the capability and willingness to supply them is exhausted, the next most needy member of the bloc will try for aid.

In general, REMOVE will take a list of willingness to offer aid to Nation-Groups and determine how much of each force type will be offered. The offers are met by reserving from the offerer's surplus the force type least effective for the area where it is located. If more aid is to be offered than exists of this type, the next to the least effective is reserved. The process continues until the total list of offers is made. The result is a table of offers including the Nation-Group who is to receive aid, the offerer, the location of the force, and the force type. If no force is offered, SHIFT goes back to the list of Nation-Group needs to select the next most needy Nation-Group.

From this list of offers the best will be selected by SHIFT, first on a cost-effectiveness basis (See Equation 4, Section 4.5.3) and second on the basis of timeliness (nearest of the most cost-effective type is selected first).

To be able to ship forces the supplying Nation-Group must have available transport units. Transport units may be in use as a result of the Nation-Group shipping too much force. Transport units are vulnerable to Naval war and may be sunk in transit, but the economy may rebuild the units in time. If the supplying Nation-Group has transport units, there must also be available shipping channels. Shipping channels are a model variable in which are stored data recording the shipment (owner, location, destination, force type, amount.) There are thirty such channels. They could all be in use. If so further shipments must wait for at least another week until a channel becomes available.

Since shipping is handled bloc by bloc, the first bloc processed could use all available channels. Therefore the order of blocs, as set by the way in which data is aggregated, may be important.

Thus in TEMPER the Nation-Group which is in the greatest need will first have an opportunity to get the most cost effective force for him. This will decrease the range of choice available to the next most needy Nation-Group, but the latter may have a different order of cost effectiveness ranking.

4.5.4 Equations in SHIFT

1. The net desired counterforce utility, before adjusting for forces in transit to the Nation-Group, is determined as follows:

$$D(A) = \left(\frac{O(B)}{K_1} \right)^2 \left(\frac{CFU(B) \times K_2}{K_3} + K_3 \right) + \left(\frac{O(C)}{K_1} \right)^2 \frac{CFU(C) \times K_2}{K_3} + K_3$$

+ BF(A) - CFU(A)

where

$D(A)$ = desired CFU of A (+ for need, - for excess)

$O(B)$ = operations level directed by A to B

$O(C)$ = operations level of C

$CFU(A)$ = A's CFU in the Conflict region

$CFU(B)$ = B's CFU in the Conflict region

$CFU(C)$ = C's CFU in the Conflict region

$BF(A)$ = A's base force (homeland) CFU requirements (for internal security, etc.)

$K_1 = 6$ Sets point at which ZDOMZ results in approximately 1:1 CFU ratio desire.

$K_2 = 1$ A unitary multiplier could be varied to supply a constant bias in force desire i.e., move the CFU ratio but keep its shape.

$K_3 = 0.1$ To always provide some small increment of desired force regardless of how small a force the opponent has.

2. Effectiveness of a force type = (Basic utility of type in area to be used) x (random campaign variable).
3. Cost of force type = (Quarterly cost to operate the type) + (cost to ship one unit).
4. Cost Effectiveness = basic counterforce utility/cost of force type.
where basic counterforce utility will be modified in a war to reflect the effect of the random campaign variable.
5. NEED = (Remaining desired counterforce utility)/(counterforce utility of one unit of most cost-effective force type).

4.6 Subroutine Force Removal (REMOVE (HELPER))

4.6.1 General Description of REMOVE

REMOVE is largely a bookkeeping section of the model which converts willingness to supply aid (as determined by LIANCE and WINOVR) into specific aid offers of amounts and types of force.

This conversion is on the basis of the cost-effectiveness of the offered force type.

REMOVE is supplied with willingness to supply aid in terms of the counterforce utility to be supplied to a needy Nation-Group (an ally or neutral) by the offerer. This willingness identifies the location of the force to be offered, but not the force type.

To convert the willingness to specific force type, a cost-effectiveness measure is made. A search of all deployed forces is made to find those least cost effective where they are located. These are used first to meet willingness to aid. Then the next most cost-effective are used, repeating the process until the total willingness to aid is represented on a list of excess forces being offered by the specific aid offers (owner, location, type, number of units, potential destination).

In the case of indigenous forces, the offerer always retains the basic force required or desired at home. This item is determined by insuring that if all surplus is taken by Nation-Groups in need, the offerer will retain the basic home force in counterforce utility units, but in a force mix by type exactly representing what existed before any aid was supplied.

4.6.2 Detailed Description of REMOVE

In the LIANCE and XLIANCE Subroutines we shall find that a Nation-Group sets aside for its own needs the counterforce utility required to meet those needs. The extra counterforce utility is then assigned, if needed, to supply the requirements of other Nations of the same bloc or of neutrals. The needs for which force is set aside are limited to ten requests of each major bloc. In establishing these requests the bloc looks first to the needs of the bloc and then to the needs of the neutral. REMOVE will identify specific force units to be offered to the needy Nation Groups. The total offers will not exceed the need (as projected the previous week in LIANCE and XLIANCE). While that projection and the actual need may

not match exactly, there will be a tendency to have the exact total needs set aside (if the willingness and ability are present) and to have each Nation-Group set aside from surplus its least cost effective forces for the requestor. REMOVE will provide for preserving for a supplying Nation Group the same mix of forces, assuming all extra forces are made available as aid, as existed before the aid was supplied.

Nation-Groups in need of force will call on REMOVE from SHIFT to see if any offers are available. If not, SHIFT will determine whether other Nation Groups are also in need. For each Nation-Group which calls it, REMOVE will prepare the list of excess force being offered. To perform its functions REMOVE first scans the list of consignments of counterforce utility supplied by LIANCE and XLIANCE for possible aid. These consignments indicate the amount of CFU, owner, location and potential receiver. If offers are available then REMOVE scans each of them and selects for each consignment the least cost effective force type available to meet the consignment commitment. If this is not enough then the next most cost effective is used. The process is repeated until, for that consignment, enough counterforce utility is set aside. The forces so set aside constitute a list of excess force from which the requesting nation may select force.

Unless the previous weeks desires registered by subroutines LIANCE and XLIANCE are substantially more than those actually needed in the current week, a requesting Nation-Group will ultimately call on all offers regardless of their cost effectiveness. The ordered way in which SHIFT calls on the offers simulates conditions where there may be limited transport units or shipping channels and where the requesting Nation-Group would be expected to ship the most cost effective forces first through the available shipping capacity.

Cost effectiveness is computed slightly differently in REMOVE than it was in SHIFT (see Equation 1, Section 4.6.3). The basic counterforce utility is modified in the same fashion but this time the shipping factor is not used in computing cost. Only the quarterly operating cost is used.

4.6.3 Equations in REMOVE

1) Cost effectiveness = effectiveness/quarterly operating cost

Where effectiveness = basic counterforce utility x random campaign variable
and random campaign variable = 1 in peacetime

4.7 Subroutine Naval Logistics (NAVLOG)

4.7.1 General Description of NAVLOG

The purpose of the Naval Logistics routine in TEMPER is to allow bloc members to move surface naval forces from their initial locations to centers of higher military tension in various parts of the world.

The Naval Logistics Subroutine provides for the movement of naval forces between the TEMPER world's seven sea conflict regions. Contiguity and sea travel information is provided in a special input parameter which stores the time to reach a destination sea, and the sea which must next be traversed to reach the destination sea. For the sake of simplicity, the model assumes that the time to move to an adjacent sea is one week. By the way in which the seas are linked to one another with this parameter, the opening or closing of a major canal can be simulated. For example, if the Mediterranean Sea and the Indian Ocean were TEMPER-world seas, the presence of the Suez Canal could be simulated by indicating that the two seas were adjacent to one another, and subsequently, one week apart. The closing of the Suez Canal could be simulated by showing the travel time as three weeks and the adjacent, en-route seas as the North Atlantic for the Mediterranean and the South Atlantic for the Indian Ocean.

The decision to move forces is made according to the desired naval operation of the allies in each of the seas. Desired naval operations in a given sea, reflects the intensity of conflict on all land conflict regions contiguous to that sea. This is based on the assumption that land conflict will extend into the adjacent Sea Conflict Regions, and all participants in the conflict will be involved.

Information on which seas are contiguous to a particular land region is contained in a second parameter. This contiguity parameter is set to indicate the extension of land conflict into a sea conflict region. If it is felt that military operations in a given land conflict region will lead to conflict in a Sea Conflict Region, the parameter is set accordingly.

NAVLOG assumes that on day zero, the desired deployment of naval forces is achieved by each bloc. Naval surface forces of neutral Nation-Groups are not redeployed, since the model assumes that neutrals do not have global goals and are concerned only with local security.

Thus, at the start the nominal naval force is set equal to the force actually located in each sea by each bloc. Each week thereafter, the desired naval force in each sea is equal to the nominal force plus the increment due to adjacent land military operations. If this total amount exceeds the actual deployment, a need exists. If the difference is negative, an excess exists.

The values of naval force need or excess computed are scanned to find the sea most in need of reinforcement. Reinforcement will occur only if there is at least one sea with an excess, and one with a need.

If reinforcement is necessary and available, the sea with the greatest force deficiency is chosen by the bloc as the sea to receive help. It is the only sea selected by the subject bloc to receive help each week, and will be called here the deficiency sea. The ally Nation-Group whose force is selected to be moved must: (1) have a force deployed in the sea with an excess nearest to the deficiency sea; (2) have the lowest level of commitment to the sea with the force excess of the ally Nation-Groups with forces deployed in the excess-force sea, and (3) have some commitment to the deficiency sea. Reinforcement will not take place if an ally Nation-Group cannot be found which has both an excess force, and a commitment to the deficiency sea. Commitment to a sea is computed as the sum of the military operations levels on all contiguous land conflict regions in which the Nation-Group with the excess force has deployed land military forces.

The closest sea to the deficiency sea is found by consulting the adjacent sea total travel time parameter, which gives travel times. Once a helping Nation-Group is selected, an appropriate amount of force is transferred to the sea one week's travel time from the sea in which the force is currently located, and in the direction of the deficiency sea. This will be the region of need itself if the travel time to the deficiency sea is one week. If not, the force has in effect been moved one week closer to the region of need. If the deficiency sea is the same the following week, the excess probably will be moved again in the direction of the deficiency sea.

There may be delays in this process and, indeed, the force may never reach its original destination. For example, this will occur if the amount of need decreases in the original deficiency sea or increases in another sea to the point where a different sea becomes the most deficiency sea.

4.7.2 Detailed Description of NAVLOG

Subroutine NAVLOG is operated for each of the two blocs, but not for the neutral Nation-Groups each week. It performs its functions completely for the West, and then repeats them for the East.

NAVLOG first computes the desired change in the total surface naval force deployed in each sea by the bloc members, ΔF_s .

$$\Delta F_s = \frac{K_6}{K_4} \sum M^2 + F_{ns} - F_{as}$$

where: ΔF_s is the desired change in the s -th sea.

$\sum M^2$ is sum of the squares of the levels of military operations of each bloc member adjacent to the s -th sea.

F_{ns} is the nominal force size in the s -th sea. F_{as} is the actual force size.

K_6 and K_4 are scaling constants.

The nominal force is established on day zero by assuming the initial deployments are as desired so that ΔF_s is zero.

Thus,

$$F_{ns} = F_{as} \text{ day zero} - \frac{K_6}{K_4} \sum M^2 \text{ day zero}$$

The level of military operations, M , by the subject bloc member, against the opponent bloc member has been set earlier by Subroutines ACBARG, CDALC, LIWAR, and FIGHT. The actual deployment is found by summing the list of individual forces located in the subject sea belonging to the subject bloc.

Generally speaking, ΔF_s will be positive in some seas indicating a desire for additional forces, and in some it will be negative indicating excess forces. The sea with the biggest need, is identified as the "worst" sea, and an attempt is made to supply it with additional forces. The nearest sea with an excess force is identified as the "best" sea. Having identified the best sea, the ally Nation-Group which has the lowest commitment to the best sea, some commitment to the worst sea, and some surface force in the best sea, is identified as the "best" Nation-Group. By moving the force having the

lowest commitment we simulate a process of withdrawal of force no longer needed which will leave the most committed Nation-Groups still involved. Using lowest commitment first has the added advantage of having a lower probability of leaving part of a Nation-Groups force behind.

Commitment C_{js} of a Nation-Group, j , to a sea, s , is given by:

$$C_{js} = M_j + \sum M_r$$

where M_j is the level of military operations if j is adjacent to the s -th sea, plus the sum of the levels of military operations, M_r , of each of the ally Nation-Groups adjacent to the s -th sea, who have ground forces supplied to them by the j Nation-Group. Thus, each Nation-Group is committed to both the seas to which it is adjacent and to the seas adjacent to other Nation-Groups where it has deployed forces, and its degree of commitment is a direct function of its level of military operations. In this way the model simulates the dependence of land conflict on adjacent seas. A committed Nation-Group will want both to obtain needed reinforcements, and to prevent the opponent from doing the same.

If the NAVLOG manages to find a Nation-Group to qualify as best, it redeploys the smallest of the following:

- a. The needed force in the "worst" sea.
- b. The excess force in the "best" sea.
- c. The total deployment in the "best" sea belonging to the "best" Nation-Group.

If the need is still unsatisfied, and there is still an excess in the "best" sea, NAVLOG will redeploy forces of the "second-best" Nation-Group in the "best" sea using the same rules as above. Otherwise, it will turn to the "second-best" sea. This process continues until either the need is satisfied, or all possible sources have been exhausted. The process is then repeated in exactly the same way for the other bloc.

4.7.3 Equations in NAVLOG

1. Nominal Naval Surface Force Deployment (computed on Day Zero)

$$F_{ns} = F_{as} \text{ day zero} - \frac{K_6}{K_4} \sum M^2 \text{ day zero}$$

where

F_{ns} = the nominal force deployment of the subject bloc in the s -th sea.

F_{as} = the actual force deployment on day zero.

M = the military operations level against the opponent bloc members of each bloc member adjacent to the s -th sea on day zero.

2. Desired Total Naval Surface Force Change

$$\Delta F_{as} = \frac{K_6}{K_4} \sum M^2 + F_{ns} - F_{as}$$

where ΔF_{as} = desired total naval surface change of subject bloc in the s -th sea. All other terms are as given in Equation 1.

3. Commitment to A Sea of A Nation-Group

$$C_{js} = \sum M_r$$

where C_{js} = the commitment of the j -th Nation-Group to the s -th sea.

M_r = the level of military operations of the ally Nation-Group (or subject Nation-Group) of each conflict region adjacent to the s -th sea in which the j -th Nation-Group has forces deployed.

5.1 Decision Maker Submodel

The Decision Maker Subroutines recognize problems, attempt to strike bargains, decide escalation or de-escalation of conflicts, and call on alliance help to reduce problems. Political alignment of neutrals and award of alliance points by alliance members is made on the basis of offers of help. Figure 5-1 shows the sequencing of the various subroutines by the Decision Maker Submodel. The Decision Maker Control Subroutine sequences the various subroutines, but does not of itself make changes to the Data Base.

DMFILE performs certain bookkeeping functions on the Data Base. It simulates a decay over time of existing ties between Nation-Groups that do not use these ties to conduct trade or offer military aid to each other. It updates strategic weapon characteristics to reflect growth in technology, adjusts the value of land to reflect added capital and recomputes the desire of each Nation-Group for land in the conflict region.

STRDM, each half year, calculates the loss to each bloc of a hypothetical nuclear war, assuming one and then the other bloc preempts, and that all strategic weapons owners participate in the wars.

PROREC determines the size of problems caused by each Nation-Group by the other two Nation-Groups in the conflict region, because of their military operations, level of deterrent threats, tactical force ratios, and unmet desire for land. PROREC also computes the perception of the problems of the other two Nation-Groups. For strategic owners, it computes the discrepancies between desired and actual strategic spending ratios, the size of the resulting problems, and a perception of the other bloc leader's problems from this source.

The Bargaining Subroutines operate in a series to perform the functions necessary to solve problems through bargaining. The Weekly Bargaining Subroutine (WEBARG) arranges perceived and real problems in arrays for processing by the Bargaining Subroutine (BARGY). BARGY determines what bargains are mutually acceptable given the perceived and

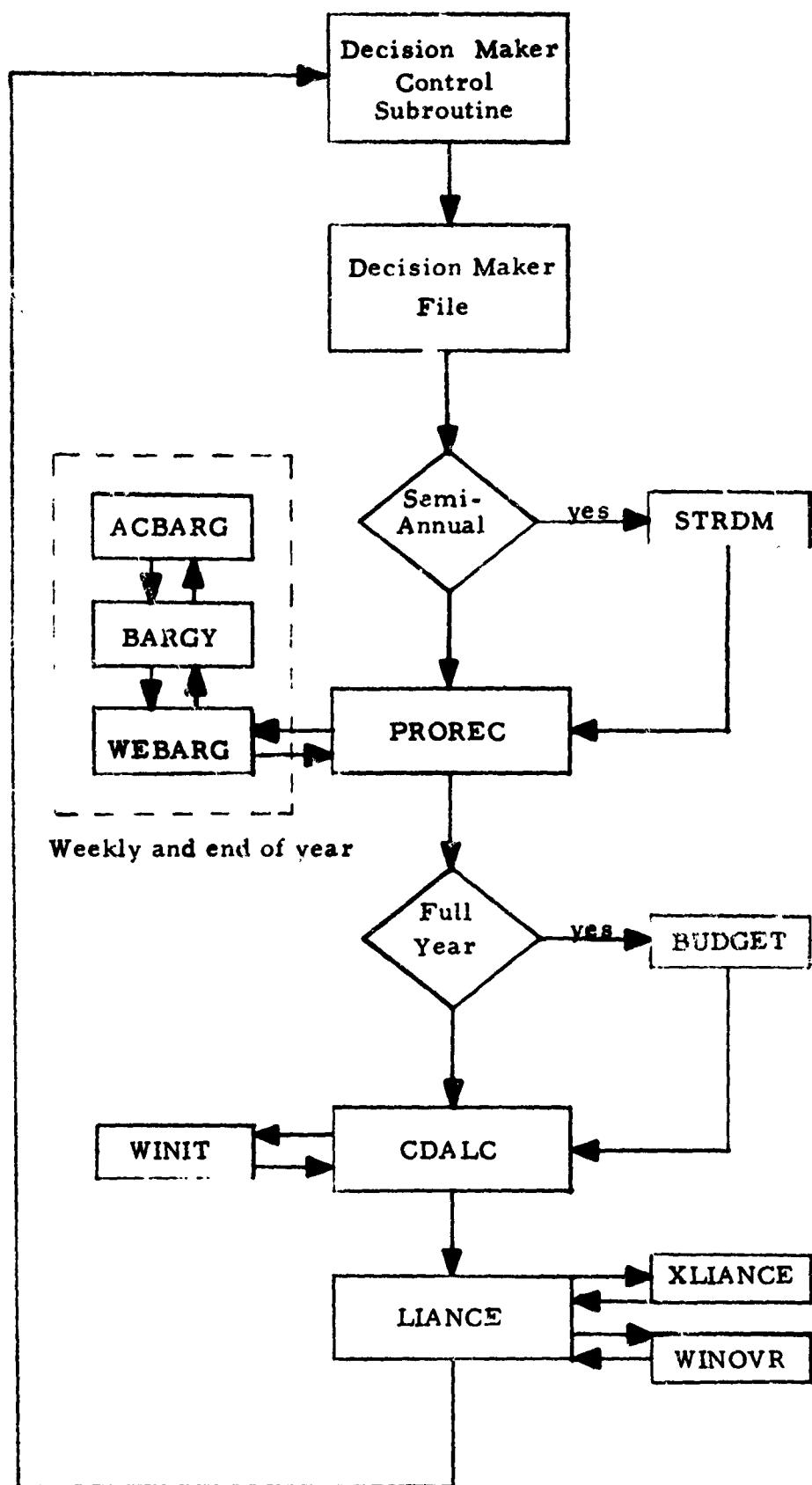


Figure 5-1 Sequencing of Various Subroutines by the Decision Maker Submodel

real problems. Finally, the Accept Bargains Subroutine (ACBARG) carries out the accepted bargains. When the forces of allies are involved in the bargain, ACBARG permits the allies to veto the bargain if a majority wish to.

At the end of each year, Subroutine BUDGET establishes the military budget for the coming year on the basis of cultural motivations and budget problems identified by PROREC.

The Command Allocation (CDALC) Subroutine determines how to fight a war, when to have a truce, and how to conduct the war (release tactical nuclear weapons, initiate strategic exchange), and if there is no war, whether the problems constitute a crisis. WINIT is called to decide to escalate, de-escalate, or maintain the status quo after which CDALC computes new values for military operations and deterrent threat.

LIANCE determines need for military aid or assistance, and XLIANCE develops for each needy nation a list of allies willingness and ability to offer aid. WINOVR, on the basis of this list, awards alliance or alignment value points to these allies for aid offered to other allies, or to neutrals respectively.

5.1 Subroutine Decision Maker File (DMFILE)

5.1.1 General Description of DMFILE

Subroutine DMFILE is called each week by control Subroutine DM to update the values of several key variables. These are as follows:

- a. The measure of inter-Nation-Group friendship, ally value, and alignment value
- b. The characteristics* of the four strategic weapon types of each bloc, vulnerability, reliability, and accuracy;
- c. Nuclear attack threshold, which is used by Subroutine WINIT as a threshold for deterrent threat; and
- d. Nation-Group land value, and desired land fraction.

The simplified flow of DMFILE is shown in Figure 5-2. DMFILE performs four functions.

Each week DMFILE causes all friendship values (ally values and alignment values) to decay slightly. If there is no trade or military aid offered so that Subroutines WINECO or WINOVR, respectively, can cause an increase, friendship value will gradually decline. This action simulates the loosening of ties of friendship in the real world when two otherwise friendly nations do not have either commercial or military relationships. The decay is proportionate to the square of the sine of the normalized friendship value as shown in Figure 5-3 .

At the end of each quarter, DMFILE recomputes the vulnerability, reliability, and accuracy of each strategic weapon type for each bloc. That is to say, that these characteristics of a given strategic weapon type will be the same for all the strategic owners in the bloc. Changes in the characteristics are a function of R & D and strategic force spending, and partly chance. The chance occurrence of technological breakthroughs is simulated using a random number generator, but as characteristics improve, further improvement becomes more unlikely.

* These quantities are only updated at the end of each quarter.

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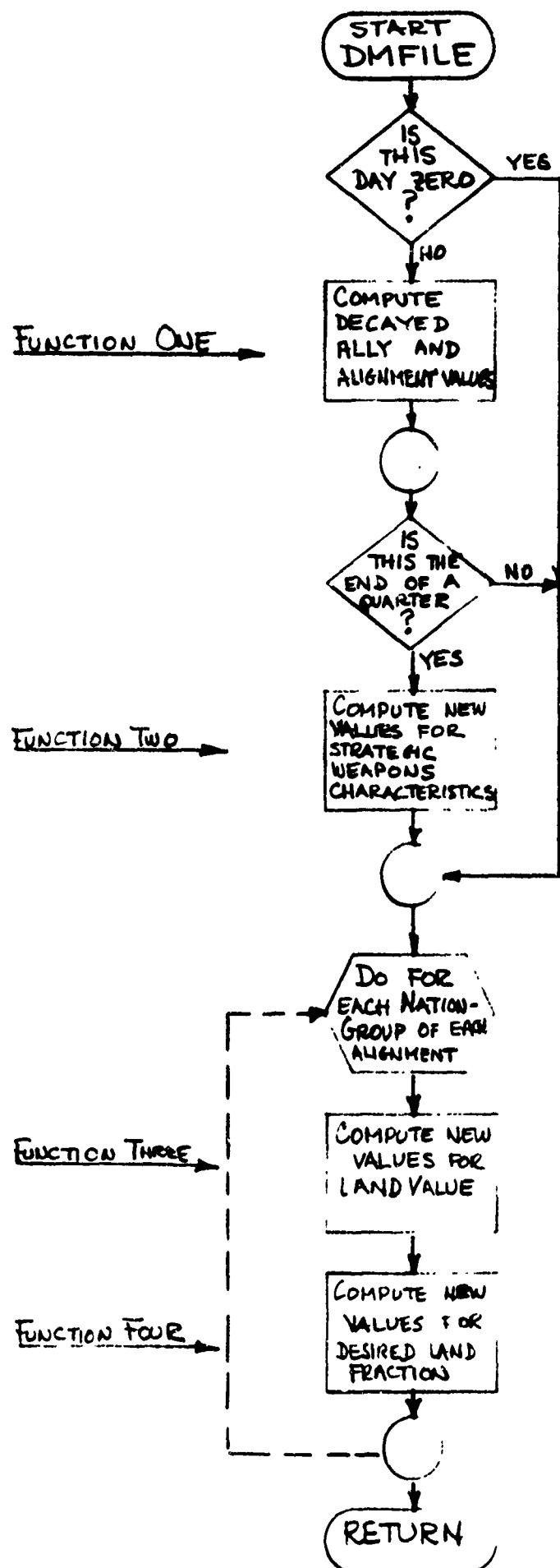


Figure 5-2 Simplified Flow of Subroutine DMFILE

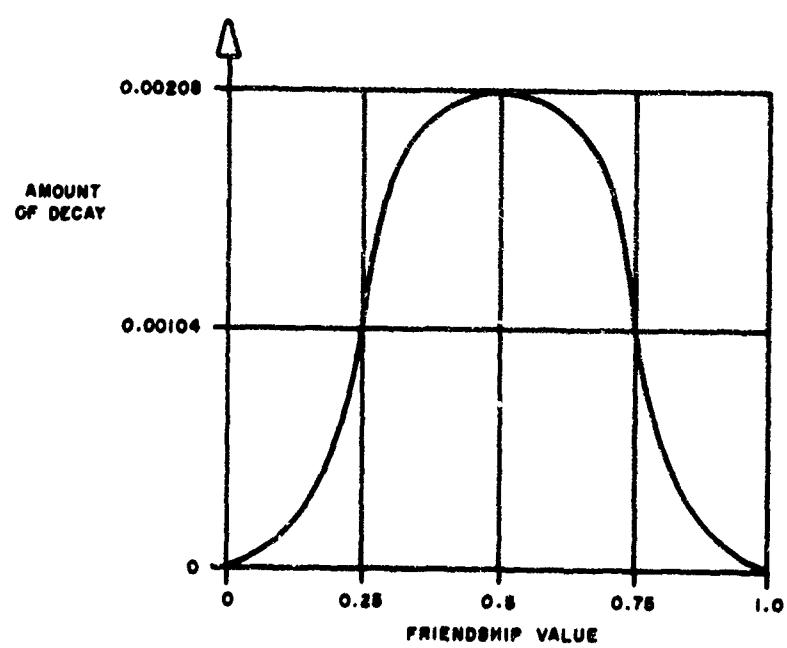


Figure 5-3 Decay of Friendship Value

Each week DMFILE computes land value, and desired land for each of the 39 Nation-Groups. Land value is the value a Nation-Group places on the land of each of the three Nation-Groups in its own conflict region. Thus, a total of nine land values are computed for each conflict region. Land value is a function of the GNP per square mile, and perceived counterforce utility ratio, and the Nation-Group's own level of military operations. At the same time, DMFILE computes the desired land fraction which exerts a powerful influence on the activities of the Nation-Group. As the name implies, desired land fraction is the fraction of the conflict region which the Nation-Group desires. The fraction desired may be more or less than the amount currently occupied. If it is larger, the Nation-Group will tend toward a limited war, so it can occupy additional territory. If it is less, the Nation-Group will tend to show less zeal in resisting pressure from the other two Nation-Groups.

5.1.2 Detailed Description of the Functions of DMFILE

The decay in ally alliance value is calculated each week using a sine squared decay function as shown in Equation 1. This decays the value most at the middle of the spectrum at or near 0.5. This seems reasonable, since the value awarded by Nation-Groups with which one is not friendly at all cannot decay much more. Similarly, very strong alliance relationships are not likely to decay rapidly; it is the "intermediate" level of friendship that is likely to change fastest.

DMFILE uses exactly the same procedure and rationale in computing the decay of alignment value. All of the preceding holds true if one substitutes "alignment value" for "ally value", and the two are referred to together as friendship value.

The key characteristics of all strategic weapon systems are updated each quarter.

The Vulnerability Number is increased for each bloc by the sum of the ratio of strategic force spending to government spending for each of the strategic owners in the bloc as shown in Equation 2. (The Vulnerability Number of a target increases with its hardness.)

Reliability is increased probabilistically for each bloc whenever reliability is less than a random number chosen between 0 and 1. The increase is the difference between the random number chosen and the current value of reliability times half the ratio of R&D spending to defense spending for each strategic owner in the bloc in turn. See Equation 3. Thus, increases are much harder to come by as reliability approaches 1. The calculation is repeated for each of the strategic owners in the bloc, and the final value of reliability is retained for use by all of the strategic owners in the bloc.

Weapon CEP is decreased probabilistically if the CEP of the weapon divided by 5 is greater than a random number chosen between 0 and 1. The new CEP is the difference between the old CEP and the random number. Otherwise, CEP is unchanged. See Equation 4. As with reliability, begin with the first strategic owner in the bloc, repeat for each other strategic owner, and retain the final value. The largest possible CEP reduction is 20 percent of the current value, assuming that the CEP was less than 5.0 nautical miles initially.

Update the deterrent threat threshold for the West and East blocs and the neutral Nation-Groups each quarter. The deterrent threat threshold is used by Subroutine WINIT to establish the minimum advantage a Nation-Group must perceive before it elects to raise its level of deterrent threat. The threshold is equal to a nominal value set initially for each bloc, less the weighted value of all war losses sustained by the Nation-Group. See Equation 5. In other words, the theory states that the greater the war losses a Nation-Group has sustained, the less its restraint in the use of deterrent threats against its opponents.

Nation-Group land value is the sum of two weighted components representing economic and military values, divided by the amount of land possessed. It is computed weekly for each Nation-Group for itself and each of the other two Nation-Groups in its conflict region as shown in Equation 6. The economic factor is proportional to the relative value per square mile of the Nation-Group compared with the value of the entire conflict region. The military factor is strongly influenced by the valuing Nation-Group's level of military operations, moderated by the perceived ratio valued to valuing

Nation-Group CFU's. The economic factor is the dominant one as shown in Figure 5-4. Thus, the value one Nation-Group places on another depends both on the value of the land, and the likelihood that it can be taken.

Each week DMFILE computes the fraction of the conflict region desired by each of the Nation-Groups in it as shown in Equation 7. The new value of desired land fraction is 97.5 percent of last week's value plus 2.5 percent of a new factor which is the current fraction of the conflict region occupied or a land value, whichever is greater. The land value factor is an average of the total value fraction placed on the conflict region by the Nation-Group, and the fraction of the conflict region which the Nation-Group thinks of itself as once owning. For example, if a conflict region were made up of North and South Korea, each might think of itself as once owning all of the conflict region. The land value for each Nation-Group as computed above is weighted as shown in Figure 5-5. If the value is below a threshold, K_5 , it makes no contribution to the land value factor; if it exceeds a second threshold, K_6 , the contribution is equal to the fraction of the conflict region occupied. Otherwise, it lies somewhere between these extremes as indicated by the figure.

Returning to the expression for desired land fraction, we can see that if a Nation-Group puts a low value on the balance of the conflict region and does not have a high historic interest, its desired land fraction will gradually decline until it equals the fraction actually occupied. If the Nation-Group increases its value of the conflict region, or feels it once occupied more than it now does, the desired land fraction will tend to rise.

5.1.3 Equations in DMFILE

1. Friendship Value Decay

$$\Delta F = \frac{\sin^2(\pi F)}{K}$$

where:

ΔF = change in friendship value

F = current value of friendship

K = a constant, currently set at 480

(The number of weeks in 10 years of TEMPER time.)

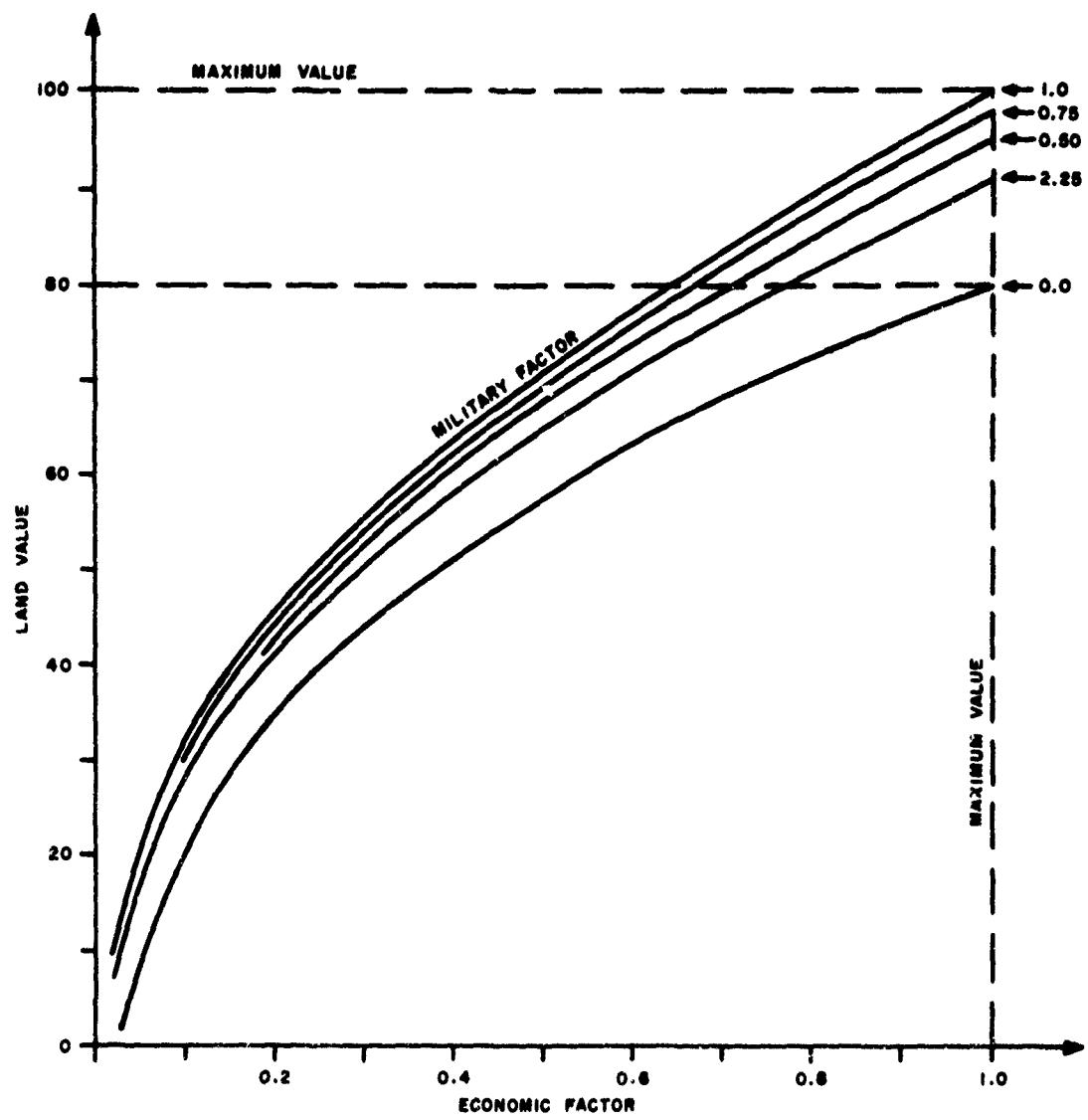
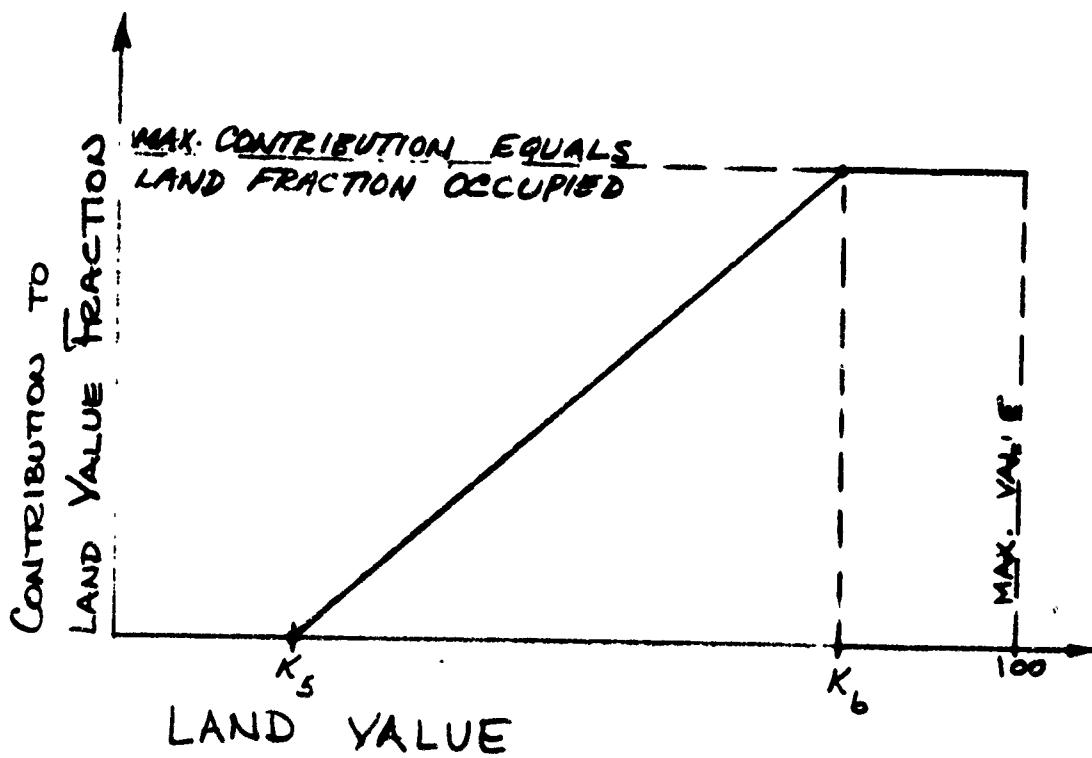


Figure 5-4 Computations of Land Value



NOTE: WEIGHTED VALUE FRACTION, WANT,
IS THE SUM OF THE CONTRIBUTIONS
FROM EACH OF THE OTHER TWO
NATION-GROUPS.

Figure 5-5 Weighted Land Value Function

2. Vulnerability Number Increment of Strategic Weapons

$$\Delta VN = \sum_{\text{bloc}} \frac{S_s}{S_g}$$

where:

ΔVN = change in strategic weapon Vulnerability Number

S_s = quarterly strategic spending

S_g = quarterly total government spending

3. Reliability of Strategic Weapons

If $R \geq r$, then $\Delta R = 0$.

If $R < r$, then

$$\Delta R = \begin{cases} \frac{1}{2} r - R & \text{if } R < r \\ 0 & \text{if } R \geq r \end{cases} \frac{S_r}{S_m} \text{ strategic owner}$$

where:

R = strategic weapon owner

r = a random number from 0 to 1

S_r = quarterly R&D budget

S_m = total quarterly military budget

4. Accuracy of Strategic Weapons

If $\frac{CEP}{5} > r$, then $\Delta CEP = -r$

If $\frac{CEP}{5} \leq r$, then $\Delta CEP = 0$

where:

CEP = weapon accuracy in nmi

ΔCEP = change in weapon accuracy

r = a random number from 0 to 1

5. Deterrent Threat Threshold

$$T_d = T_{dn} - K_2 \sum_{\text{all wars}} (\text{War Loss})$$

where:

T_d = deterrent threat threshold

T_{dn} = nominal threshold

(War Loss) = total dollar loss in each war in which the Nation-Group
is involved

K_2 = a constant currently set at 1.0

6. Land Value

$$V_{a-b} = K_3 \sqrt{R} + K_4 \sqrt{R} \cdot P$$

where:

V_{a-b} = the value "a" puts on the land of "b". "a" equals
"b", when "a" values itself and it sets $P = 1$.

R = the economic factor

P = the military factor

K_3 = a constant currently set at 80

K_4 = a constant currently set at 40

6a. Economic Land Value Factor

$$R = \frac{QGNP_b}{F_b} \sum \frac{QGNP}{F}$$

where:

$QGNP_b$ = the quarterly GNP of "b"

F_b = the fractions of the conflict region occupied by "b"

The denominator is the sum of this ratio for the three members
of the conflict region.

6b. Military Land Value Factor

$$P = \min \left\{ 1.0, \text{ or } \frac{1}{2} + 0.4 \tan \left[\frac{MO_{ab} - T - 5.0}{2.0} \right] \right\}$$

where:

"min" means take the smaller quantity inside the braces

MO_{ab} = the level of military operations of "a" against "b"
ranging from zero to 10.

T = a function of the CFU ratio as follows:

$\frac{CFUP_b}{CFU_a}$	T
< 0.1	-1.0
0.1 < 0.667	$\frac{0.1}{CFU \text{ Ratio}}$
0.667 < 1.5	0.0
1.5 < 10.0	$\frac{10.0}{CFU \text{ Ratio}}$
< 10.0	1.0

where:

$CFUP_b$ = "a's" perception of "b's" CFU, tactical force utility.

CFU_a = "a's" CFU

IF $CFUP_b = 0$, then $P = 0$.

7. Desired Land Fraction Change

$$\Delta df_a = K_7 \left\{ \max (G, f_a) + df_a \right\}$$

where:

K_7 = a constant currently set to 0.025

"max" = means take the larger of the two quantities G, and f_a

G = the land value factor

f_a = the land fraction occupied by "a"

df_a = the land fraction desired by "a"

7a. Desired Land Value Factor

$$G = \frac{1}{2} \left\{ W - Hf_a \right\}$$

where:

W = the sum of the values (each weighted as shown in
Figure 5-5) of all three Nation-Groups in the
conflict region as evaluated by Nation-Group "a"

Hf_a = land fraction historically occupied by Nation-Group "a"

5.2 Subroutine Strategic Decision Maker (STRDM)

The purpose of the Strategic Decision Maker is to compute the outcome of a global nuclear exchange in terms of population loss first assuming the Western bloc preempts, and secondly, assuming the East bloc preempts. A pure counterforce strategy is assumed for both; that is that the strategic weapons of each bloc are the targets for the weapons of the other bloc. Population loss is assumed to be a result of fallout from these counterforce strikes and so is a measure of the success of the attempt to limit damage by use of counterforce targeting. These calculations simulate the loss estimates which are made by the leadership of the two blocs when weighing the consequences of a nuclear exchange

5.2.1 General Description of STRDM

In computing the results of each of the two hypothetical wars, STRDM makes the following assumptions:

- a. All the strategic weapons in existence are used.
- b. Each bloc acts as a single entity.
- c. All weapons are targeted against opponent strategic weapons.
- d. The sequence of events is fixed as the following:
 1. The preemptor launches his missiles and strategic aircraft.
 2. The defender becomes aware of the attack and is able to launch some fraction of his force. The fraction simulates the response time of the strategic force and early warning system, and may be set from zero to unity.
 3. Some of the remaining forces of the defender are destroyed in part by the preemptor missiles.
 4. Of the forces which survive, the defender launches the balance of his strike, reduced in proportion to his losses.
 5. Of the forces remaining to the preemptor, some are destroyed by the defender's missiles.
 6. The defender's force is further reduced by losses from the preemptor's strategic aircraft.

7. The preemptor's force is further reduced by losses from the defender's strategic aircraft.

These events are shown graphically in Figure 5-6 in terms of the strategic weapon inventories of the two blocs.

There are four strategic force types; hidden missiles, located missiles, submarine launched ballistic missiles, and strategic aircraft. Each is described by the following characteristics which are updated by Subroutine DMFILE, Section 5.1.

Accuracy

Vulnerability Number (the land based weapons are assumed to be P-type targets)

Yield

Location Accuracy, the accuracy with which the weapon has been located by the other bloc in nautical miles.

The subroutine computes the effect on forces of each of the seven steps, and records the total number of each weapon type that detonates over enemy territory. These totals are then used to compute the total fallout, and in turn the population loss, an assessment of the ability of the strategic force to limit damage to self by making a counterforce strike.

5.2.2 Detailed Functions of STRDM

The simplified flow of STRDM is shown in Figure 5-7, and is described below.

First, STRDM deals with weapon effectiveness. The single shot miss probability is computed for each strategic weapon of each bloc used against each of the strategic weapons of the other bloc, i. e., an array $2 \times 4 \times 4$ or 32 in size. The first step is to compute the effective kill radius ratio for each weapon against each opponent weapon as a target. See Equation 1.

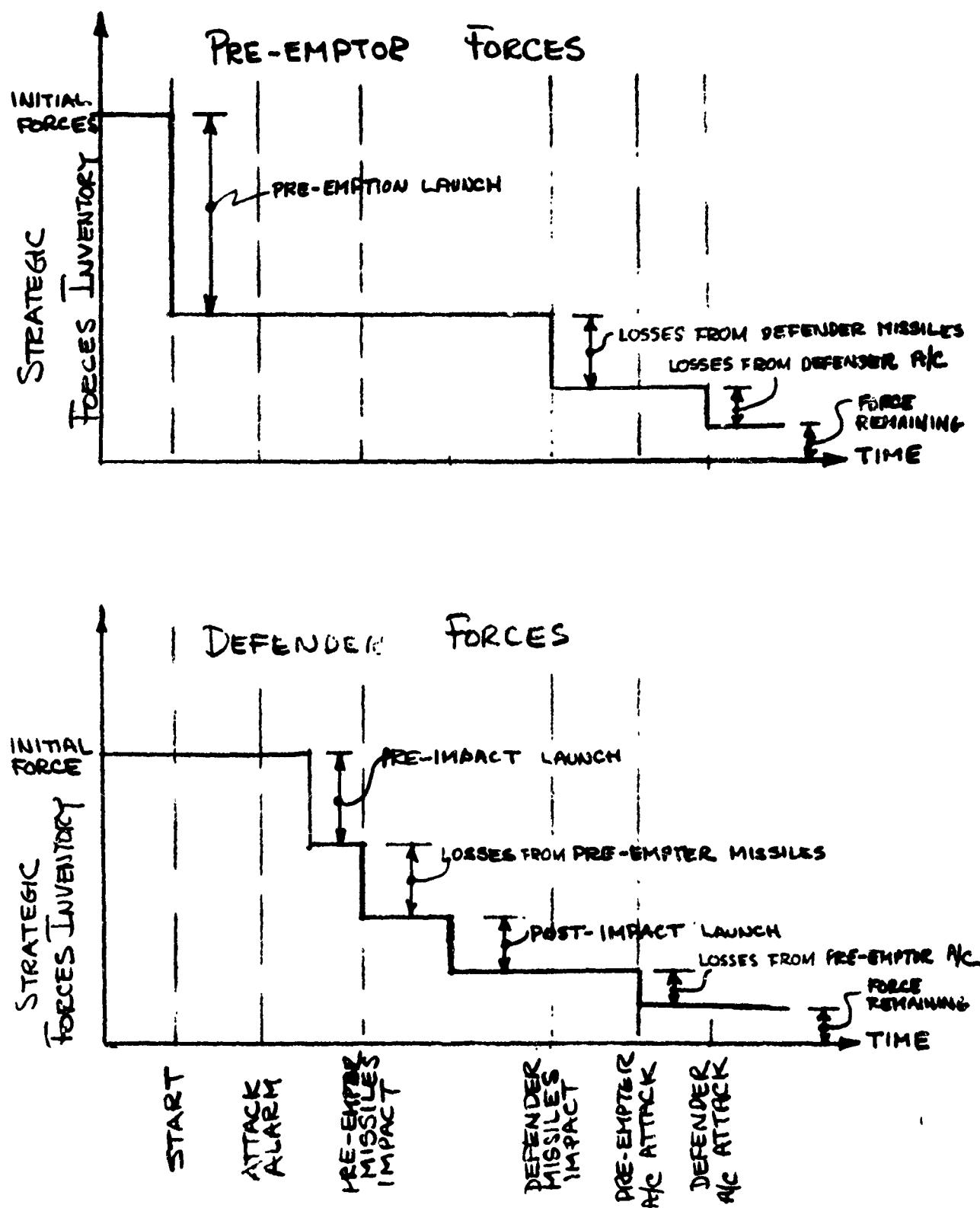


Figure 5-6 Sequences of Events in Hypothetical Nuclear Exchanges

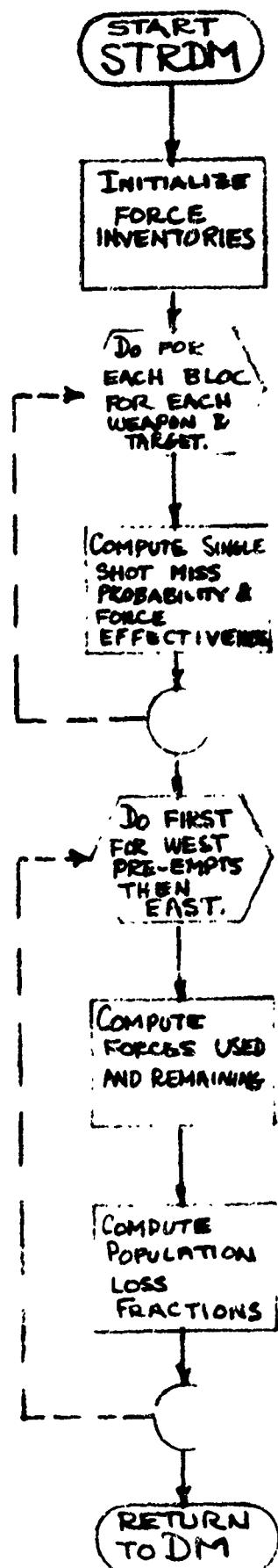


Figure 5-7 Simplified Flow Diagram of Subroutine STRDM

The effective kill radius ratio is used to evaluate the standard Gaussian integral between the limits zero, and the kill radius, to find the probability of a kill or miss. The simulation uses four linear approximations of the integral to compute the single shot miss probability, as shown in Equation 2.

A generalized effectiveness figure is computed for each weapon against each target for later use by STRDM. It is a function of the single shot miss probability, and a basic effectiveness parameter.

All of the remaining functions are performed with Bloc 1 (the West) as the hypothetical attacker, and Bloc 2 (the East) as the hypothetical defender. When all functions have been performed, the simulation returns to Function Two and repeats them with the roles reversed.

The following steps are performed for each target weapon in turn.

- a. Calculate the weapon forces of the defender which remain on the ground as targets for the preemptor's first strike.

The defender's initial force is depleted by the percentage of each force type which he is able to launch as planned before the arrival of the strike, multiplied by the percentage (which may range from 0 to 100 percent) which he planned to use. Both these percentages are set by the analyst to reflect his best estimate of real world capabilities and doctrine.

The planned targeting is recorded as an array, which is the percentage of each force type which the defender plans to launch against preemptor targets before the arrival of the first strike.

- b. The force calculated above is now diminished by the losses due to the arrival of the attacker's missiles. The loss is a function of weapons per target site (weapons are assumed to be distributed uniformly) and the single shot miss probability as shown in Equation 3.

- c. The defender's remaining forces are further diminished as a result of the percentage launched as a second retaliatory attack after absorbing the first strike loss just computed, but before absorbing losses due to the coming aircraft attack.

d. The resulting quantity is now diminished by the forces destroyed by aircraft attack; this is computed by multiplying by the cumulative miss probability of the aircraft attacks on each target. See Equation 4.

STRDM then predicts the attacker's forces after an exchange. This calculation is similar to that for the computation of the defender's force losses calculated for the defender.

a. His initial forces are reduced by the percentage of each force he targeted against all four of the defender's force type.

b. His initial forces are further reduced by the amount of those destroyed by the defender's retaliation before impact of his own missiles and the defender's retaliation after impact.

Thus, the equation used to calculate the forces remaining to the attacker L after his attack and counter-attack absorption is as given in Equation 5.

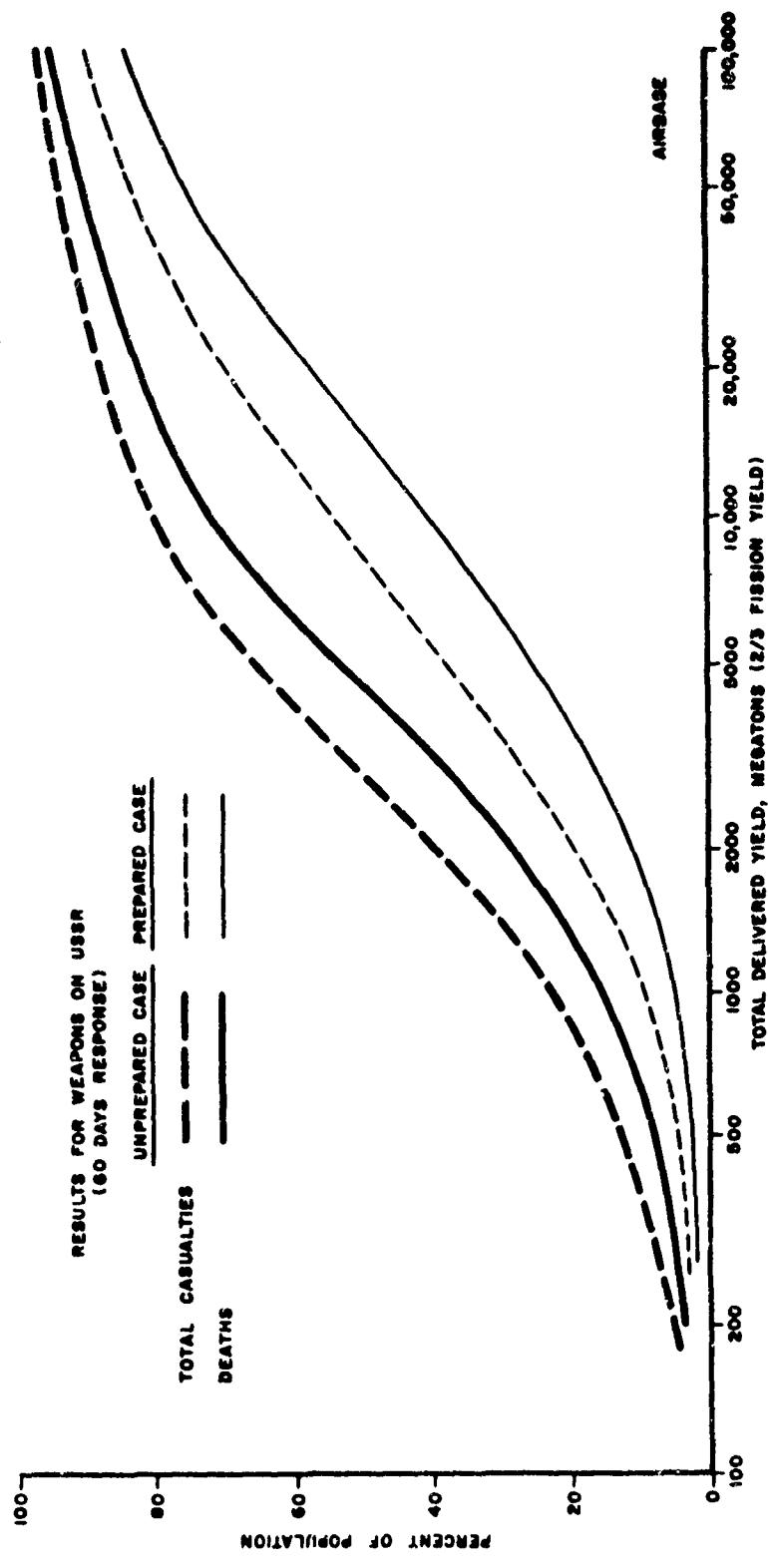
Fission megatons for the attacker dropped on the defender are determined to use in calculating population loss.

The megatonnage of equivalent fallout is the product of the number of kilotons dropped multiplied by one thousandths to scale it to megatons, the fission fraction of a bloc's weapons and the number of weapons which the bloc has been able to launch summed over all weapons and targets. This is shown in Equation 6.

The potential fission megatonnage, which could result from a use of the remaining forces on each side is computed as though the remaining force were used in a later attack. See Equation 7.

The population loss computation is based on the work by Everett and Pugh, Simple Formulas for Calculating the Distribution and Effects of Fallout in Large Nuclear Weapon Campaigns (with applications). Figure 5-8 is taken from this reference, and is typical of the loss calculations. The population loss is approximated with a negative exponential function as shown in Equation 8, and is the fraction of the population killed.

Figure 5-8 Airbase Targeting



A scaling factor which sets the megatonnage at which the loss fraction is 0.63 (i.e., the exponent is unity), currently is set at 7500 for both blocs. It simulates the degree of protection provided to the population. The higher the value, the greater the fallout required for a given loss.

STRDM, having completed the computations for a preemption by Bloc 1 now returns to Function Two and repeats these functions, with the roles reversed.

5.2.3 Equations in STRDM

1. Kill Radius Ratio

$$R_k = \frac{0.55 \sqrt[3]{W}}{\sqrt{CEP^2 + CEPT^2}} 0.10^{-0.048(VN + 0.63)}$$

where:

R_k = kill radius ratio

W = weapon yield in kilotons

CEP = weapon CEP in nmi

$CEPT$ = target location CEP in nmi

VN = target vulnerability number, the first portion of the standard VN number.

1a. Target Vulnerability Number is defined by USAFR-200-8 as

$$VN = 12.63 \log (\text{psi}) - 0.63$$

where:

VN is defined in Equation 1.

psi = 50 percent kill probability overpressure in psi for the target, and is related to distance from ground zero as follows:

$$\log (\text{psi}) = C_1 \log (\text{distance}) + C_2$$

These various constants combine to give the constants for the exponent in Equation 1.

This expression is an approximation of Figure 3.66 of The Effects of Nuclear Weapons, April 1962, USAEC.

2. Single Shot Miss Probability

$$\text{If } R_k < 0.7, \text{ then SSMP} = 1 - R_1 \{ 0.75 R_k \}$$

$$\text{If } 0.7 < R_k < 1.0, \text{ then SSMP} = 1 - R_1 \{ 0.52 + 0.53 (R_k - 0.7) \}$$

$$\text{If } 1.0 < R_k < 2.0, \text{ then SSMP} = 1 - R_1 \{ 0.68 + 0.32 (R_k - 1.0) \}$$

$$\text{If } 2.0 < R_k <, \text{ then SSMP} = 1 - R_1 \{ 1.0 \}$$

where:

SSMP = single shot miss probability of the weapon against target.

R_1 = the weapon reliability as computed by DMFILE, Section 5.1.

R_k = kill radius ratio as computed in Equation 1 above.

3. Post Impact Defender Force Inventory, F_c

$$F_c = F_b \{ 1.0 - P_1 \} \{ P_{a1} \} \{ P_{a2} \} \{ P_{a3} \}$$

where:

F_c = the post impact defender force inventory of a given weapon. See Figure 5-6.

P_1 = the percent launch before impact

P_{a1} = the total miss probability of attacker weapon type, 1, etc.

F_b = the defender's initial inventory of the target weapon type.

3a. Total Miss Probability

$$P_{an} = (SSMP_n)^{R_n}$$

where:

$SSMP_n$ = the single shot miss probability of the nth weapon type against the target.

R_n = the number of the nth weapon type impacting on each of the target sites.

3b. Weapons Per Target Site

$$R_n = \frac{F_{an} \cdot t_{na}}{F_d \cdot N_d}$$

where:

F_a = the attacker's initial inventory of weapon type n.

t_{na} = the percentage of the nth weapon type to be used against the target.

F_d = the defender's initial inventory of the target weapon type.

N_d = the number of the target weapon type at each site.

4. Defender's Final Force Inventory

$$F_{fd} = F_c \{1 - P_2\} \{P_{a4}\}$$

where:

F_{fd} = the defender's final force inventory.

P_2 = the percentage of the force launched after impact of the attacker's missiles.

P_{a4} = total miss probability of the attacker aircraft attack against the target. See Equation 3a above.

5. Attacker's Final Force Inventory

$$F_{fa} = F_a \{1 - P_3\} \{P_{d1}\} \{P_{d2}\} \{P_{d3}\} \{P_{d4}\}$$

where:

F_{fa} = the attacker's final inventory of the given weapon.

F_a = the attacker's initial inventory.

P_3 = the percentage launched as the first strike.

P_{dn} = the total miss probability of the defender's nth weapon type. See Equation 3a.

6. Equivalent Fallout Megatonnage

$$M_n = 0.001 F_n \sum_{m=1}^4 W_m \cdot N_m$$

where:

M_n = the equivalent fallout megatonnage dropped by the nth bloc.

F_n = the fission fraction of all warheads of the nth bloc.

W_m = the yield in kilotons of the mth weapon.

N_m = the number of the mth weapon dropped by the nth bloc.

7. Potential Equivalent Fallout Megatonnage

$$PM_n = 0.001 \sum_{m=1}^4 W_m \cdot F_{fm} \cdot E_m$$

where:

PM_n = the potential equivalent fallout megatonnage of the nth bloc.

F_{fm} = the final (i. e., remaining) inventory of the mth weapon.

E_m = the generalized effectiveness of the mth weapon.

7a. Generalized Weapon Effectiveness (a part of Function One).

$$E_m = \prod_{n=1}^4 E_{mn} \left\{ 1 - SSMP_{mn} \right\}$$

where:

E_{mn} = a nominal effectiveness of the m th weapon against the n th target as set by the analyst.

$SSMP$ = the single shot kill probability. See Equation 2.

8. Population Loss Fraction

$$LOSS_{mn} = e^{- \left\{ \frac{M_m + PM_m}{S_n} \right\}}$$

and,

$$LOSS_{mm} = e^{- \left\{ \frac{M_n + PM_n}{S_m} \right\}}$$

where:

$LOSS_{mn}$ = the fraction of the population of n lost when m preempts.

$LOSS_{mm}$ = the fraction of the population of m lost when m preempts.

S_n = the fallout shelter parameter for n .

S_m = the fallout shelter parameter for m .

$M_m + PM_m$ = the total fallout equivalent megatonnage dropped by m on n .

$M_n + PM_n$ = the total fallout equivalent megatonnage dropped by n on m .

5.3 Subroutine Problem Recognition (PROREC)

5.3.1 General Description of Subroutine PROREC

The PROREC subroutine has the function of recognizing problem situations and determining their size. It does this by comparing ideal values for certain variables with the actual values. The discrepancies between the ideal and real values are weighted according to the importance of the variable, and a problem matrix is set up, so that an impetus will exist for each Nation-Group to strive to push the real values closer to the ideal values. PROREC performs a total of five functions for two problem classes, internal and external as follows:

- a. Discrepancies in the defense budget breakdown are computed for strategic force owners quarterly.
- b. "Perceived Opponent" bloc leader budget discrepancies for bargaining are computed quarterly for each bloc leader.
- c. Defense budget problems and the average tax rate are computed quarterly for each Nation-Group.

The general equation for determining internal problem size from an ideal-real discrepancy is as follows:

$$P_i = (PM_i * OC_i - AC_i) = \text{Ideal-Real Discrepancy}$$

where:

P_i = problem of the i th type.

PM_i = problem motivation, i.e., desired superiority ratio.

OC_i = perceived opponent condition.

AC_i = own condition.

- d. Each Nation-Group in a conflict region can have problems due to the military operations, deterrent threat, and tactical force strength of each of the other two Nation-Groups in the conflict region, and because of its desire for their land. These four problems are computed weekly for each of the six Nation-Group permutations in each conflict region.

e. These same four problems are recomputed as they are perceived. That is to say, each Nation-Group estimates the problems it is causing others in these same areas.

Three strategic force discrepancies are computed as follows:

- a. Research and development expenditure discrepancy.
- b. Strategic force expenditure discrepancy.
- c. Tactical force expenditure discrepancy.

The discrepancies consist of annual extrapolations from the available quarterly data. The magnitudes depend upon basic motivation established in the Psychological Submodel. The motivations are essentially desired power ratios and are computed on the basis of bloc leader actions such that each strategic owner follows the example set by the bloc leader.

The two bloc leaders prepare estimates of the magnitude of their opponent's problems for bargaining, using perceived values for the opponent's motivations and expenditures, and real values for his budgets. The calculations are exactly parallel to those of strategic force discrepancies except the defense expenditure is included.

This is the percentage of the government budget desired for defense spending. The discrepancy is the difference between want and actual expenditure. The average tax rate is also computed for the BUDGET subroutine.

The trade command prescribes the amount of demand which the Nation-Group may attempt to satisfy through trade in each of the four tradeable sectors. Unsatisfied demand, excess inventory and the balance of payments are considered in computing trade command to simulate real world actions.

Nation-Group problems are determined weekly. Each Nation-Group is considered twice, once with respect to each of the other two Nation-Groups in turn as an adversary. The function computes the problem components caused by military operations, deterrant threat, tactical force strength ratio, and desired land. These problem components are employed as bargaining variables in the Weekly Bargaining Subroutine, WEBARG, (see Section 5.4) which is called by PROREC when the problem array for a conflict region is complete.

The military operations problem is a function of the deterrent threat against the opponent plus the opponent's level of military operations. In effect, if the opponent's military operations reach the level at which deterrent action has been threatened, the Nation-Group has a problem deciding whether to take the action or reduce the threat.

The deterrent threat problem is the opposite of the military operations component. The subject Nation-Group's threatened deterrent is compared to the perception of the object Nation-Group's military operations level. In effect, if the object Nation-Group has reached a level of military operations high enough to conflict with the deterrent threat of the subject Nation-Group, the subject Nation-Group has a problem.

The tactical force difference problem is a function of perceived enemy total tactical force utility (CFU) and the subject Nation-Group's actual total tactical force utility. The desired land problem is the difference between land desired by the subject Nation-Group, and land held, intensified by the value of the land itself. Land value is computed in Subroutine DMFILE; see Section 5.1.

Problems for bargaining are perceived weekly for the Nation-Groups that are members of either bloc, but not for neutrals. These perceived problems are the subject Nation-Group's estimates of the opposing bloc member's problems magnitudes and are used in making potentially acceptable bargaining offers. The computations are like those used in determining weekly problems, except that perceived and real values are interchanged.

5.3.2 Detailed Description of PROREC

The first three functions of PROREC are performed at the end of each quarter and are not performed on day zero.

First, the yearly strategic budget problems of each strategic owner are updated as shown in Equation 1d.

Each quarter a budget problem component is computed and used to develop a problem expressed in annual terms. At the end of the year, the problem will consist of the sum of each of the quarterly components. Each quarterly component is the subject Nation-Group's quarterly spending multiplied by the term:

(desired spending ratio) $\frac{\text{perceived opponent bloc leader spending}}{\text{own bloc leader spending}} - 1.0$

Thus, if the bloc leader spending ratio multiplied by the desired power ratio is unity, the term is zero and the problem component will be zero. If the product is greater than one, i.e., the spending ratio is greater than desired; the problem component will be positive. The size of the problem is computed for R&D spending, strategic forces spending, and conventional forces spending.

Next, Subroutine PROREC computes an array of four problems which each bloc leader perceives for the other bloc leader. These problems are used each year by the yearly bargaining function. They are as follows:

- a. defense spending
- b. R&D spending
- c. strategic forces spending
- d. conventional forces spending.

All are computed in the same way as the subject Nation-Group problems except perceived values are substituted for real values as appropriate. Details are given in Equation 2.

At the end of the quarter, PROREC computes for all Nation-Groups problems resulting from the discrepancies between desired and actual military spending, it computes the average tax rate, and it updates the trade demand command for each tradeable sector of the economy.

The expression for the military spending problems is in the same form as that used in determining the perceived bloc leader's military spending problem, except that the actual values for the Nation-Group are used. See Equation 2. The tax rate problem is computed by taking an average of the desired tax rate and the previous values as shown in Equation 3.

The trade demand command is updated for the four tradeable sectors of the economy:

- light industry (consumer goods)
- heavy industry (durable goods)
- agriculture
- mining (or resources development).

It will be used at the end of the next quarter by Subroutine PDCNTL. The change in the trade demand command depends on two factors:

- a. The difference between excess inventory, and unsatisfied demand, in each sector normalized by 1/6 of GNP, after the Production Control (PDCNTL) and Trade Control (CONTRA) subroutines have been operated to satisfy demand internally. If excess inventory is greater than unsatisfied (net excess supply), then this tends to reduce the command. If there is a net demand, it tends to rise.
- b. The cumulative balance of payments, weighted by GNP. For a positive (favorable) cumulative balance of payments, the trade demand command tends to rise. For a negative (unfavorable) cumulative balance of payments, it tends to fall.

The change can, in any given quarter, be only 3/10 of the difference between the present value and the limit, 0 or 1, depending on whether the change is negative or positive. The computation used is shown in Equation 4.

Each week PROREC computes the problem each Nation-Group has with respect to each of the other two Nation-Groups in its conflict region. The problem is the sum of four component problems:

- a. Subject Nation-Group deterrent threats and Object Nation-Group military operations. See Equation 5a.
- b. Subject Nation-Group military operations and Object Nation-Group deterrent threats. See Equation 5b.
- c. Difference between Object Nation-Group and Subject Nation-Group tactical force utilities. See Equation 5c.
- d. The difference between the land fraction desired and actually occupied by the Subject Nation-Group. See Equation 5d.

The first two problems have the form, $k \cdot \tanh(A)$ where k is an intensity scaling constant, and A is either the difference between the deterrent threat (real or perceived), plus the current military operations level (perceived or real) and 10. When A is positive, the problem is positive and when A is negative the problem is negative.

In effect, the term:

$$(\text{deterrent threat})_n + (\text{military operations})_m - 10$$

states that if the military actions of Nation-Group n and the threats of the Nation-Group m exceeds 10, one or the other will have to back down, or conflict will result. The hyperbolic tangent function, \tanh , is used to moderate the effect of very high values. See Equations 5a and 5b.

The tactical force difference problem computed as the inverse hyperbolic sine of the difference between the perceived tactical force utility of the object Nation-Group and the actual tactical force utility of the subject Nation-Group. If the difference is negative, the problem is negative. In other words, if the subject Nation-Group has the larger tactical force utility, the size of its overall problem is decreased. See Equation 5c.

The problem is shown graphically in Figure 5-9 as a function of the difference in the force utilities.

The fourth component is a function of the difference between land desired and land held, but in no case is less than zero. If the recent average value which the subject Nation-Group has placed on the land of the object Nation-Group is below a threshold, the desired land component of the problem is set to zero. See Equation 5d. (See Subroutine DMFILE, Section 5.1, for details.)

The total problem presented to the Subject Nation-Group by the Object Nation-Group is found by summing the four components. See Equation 5e.

Finally, PROREC computes the same four problems as each bloc member Nation-Group perceives its opponent Nation-Group's problems to be. This function is not performed on day zero. Neutrals are never Subject or Object Nation-Groups for this function, since the perceived problems are used in intra-conflict region bargaining in which neutrals do not participate.

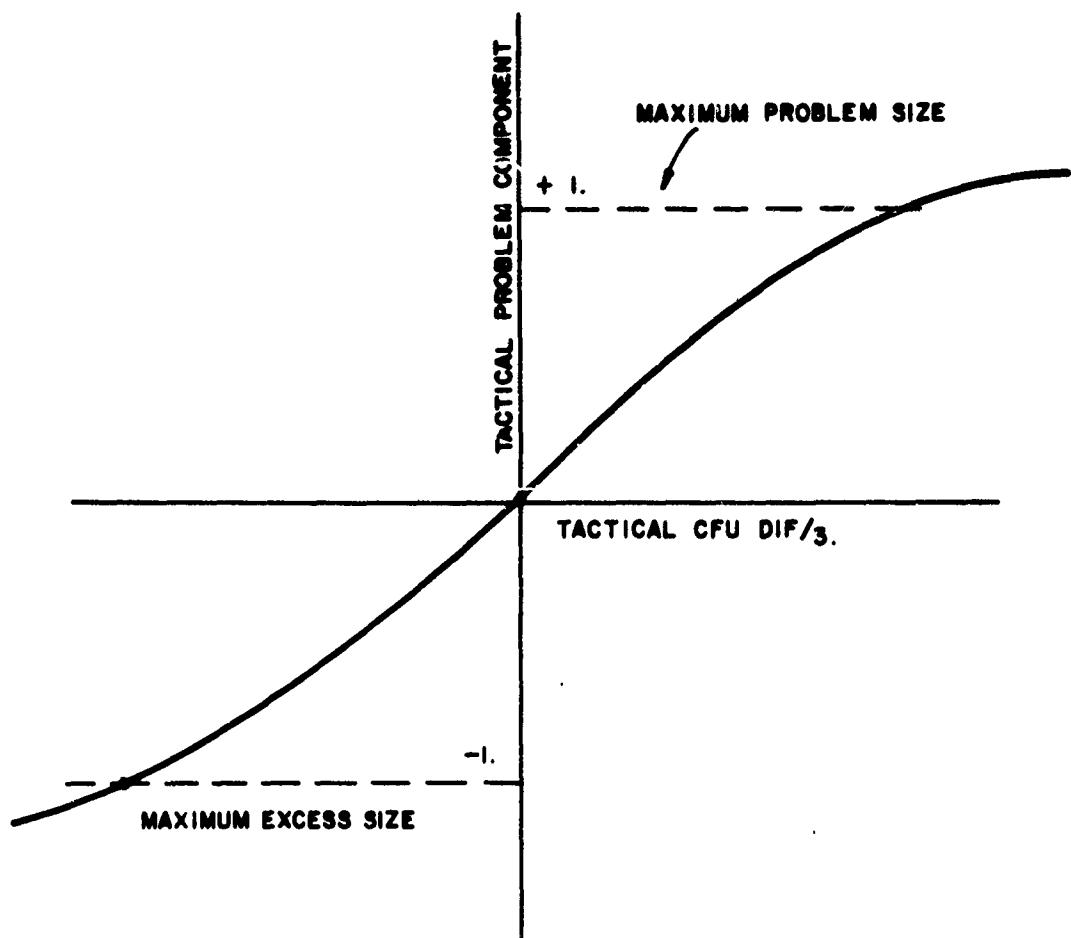


Figure 5-9 The Relationship Between Tactical Counterforce Utility Difference and the Corresponding Problem Component

The Subject Nation-Group perceives the military operations problem of the Object Nation-Group to be the same as its own deterrent threat problem. Likewise, the deterrent threat problem of the Object Nation-Group is perceived by the Subject Nation-Group as the same as its own military operations problem.

The tactical forces difference problem is computed in exactly the same way except that the sign of difference in tactical force utilities is reversed. The perception of the desired land problem is computed in the same way except the perception of desired land is used.

When these functions have been completed for all the Nation-Groups in the conflict region, PROREC calls Subroutine WEBARG (Weekly Bargaining) which is described in detail in Section 5.4 if a conflict region's bargaining control parameter is not zero; (otherwise, WEBARG is not called). (This permits simulation of a situation in which the members of a conflict region refuse to bargain with one another.) When WEBARG returns control to PROREC, it returns to determine the percentage of the government budget desired for defense spending, and repeats the steps for the next conflict region. This process is repeated until all conflict regions have been considered. If the current week is the end of a year, Subroutine WEBARG is called once more for annual bargaining of the bloc leader's problems. See Section 5.4, page 170. In either event, PROREC has then completed its functions and returns control to Subroutine DM.

5.3.4 Equations in PROREG

1. Strategic Owner Defense Budget Problems

The following are computed for R&D spending, strategic force spending, and conventional force spending.

$$P_n = S_n \left\{ R_\sigma \cdot \frac{S_{onl}}{S_{nl}} - 1 \right\}$$

where: P_n is the budget problem computed at the end of the nth quarter.

S_n = the subject Nation-Group spending in the nth quarter.

S_{nl} = the nth quarter bloc leader spending.

S_{onl} = the opponent bloc leader nth quarter spending as perceived.

R_σ = the desired ratio of own to opponent spending.

P_A = the budget problem is normalized to an annual level as shown below:

Quarter End

1a. First $P_A = 4 P_1$

1b. Second $P_A = 2 P_1 + 2 P_2$

1c. Third $P_A = 4/3 P_1 + 4/3 P_2 + 4/3 P_3$

1d. Fourth $P_A = P_1 + P_2 + P_3 + P_4$

2. Perceived Bloc Leader Problems

$$P_{np} = \left\{ R_{pp} S_{nl} - S_{nlp} \right\}$$

where:

P_{np} = perceived problem component for the opponent bloc leader.

R_{pp} = perceived spending ratio desired by the opponent bloc leader.

S_{nlp} = perceived opponent bloc leader quarterly spending.

S_{nl} = own bloc leader quarterly spending.

P_{np} spending problems are computed for total military, R&D, strategic forces, and conventional force. The perceived problem, normalized to an annual level, is computed from P_{np} as in Equations 1a through 1d.

3. Tax Rate Problem

$$P_{tn} = \frac{(n-1) R_n + T_m}{n}$$

where n = the number of the current quarter

P_{tn} = the nth quarter tax rate problem.

R_n = the tax rate used in the nth quarter.

T_m = tax rate motivation

4. Trade Demand Command

The value of the command is computed separately for each of the four tradeable sectors of the economy.

$$\Delta C_i = 0.1 C_i \left\{ \tanh (A) \pm 1 \right\}$$

where:

ΔC_i = the change in the trade demand command in the ith sector.

C_i = the previous value

$$A = \frac{6}{QGNP} \left\{ D_i - I_i \right\}$$

where:

$QGNP$ = total quarterly GNP (all six sectors)

D_i = demand in the sector

I_i = inventory in the sector.

The plus-and-minus sign takes the same sign as the balance of payments, where a positive balance means money due the subject Nation-Group.

5a. Local Deterrent Threat Problem

$$P_t = k_1 \cdot \tanh \left\{ \frac{T_s + MO_{op} - 10}{k_2} \right\}$$

where:

P_t = problem from own deterrent threat

k_1 = a constant

T_s = own level of deterrent threat

MO_{op} = perceived opponent level of military operations

k_2 = a constant

5b. Local Military Operations Problem

$$P_M = k_2 \cdot \tanh \left\{ \frac{MO_s + T_{op} - 10}{k_2} \right\}$$

where:

P_M = problem from own military operations

MO_s = own level of military operations

T_{op} = perceived opponent's level of deterrent threat

5c. Tactical Force Difference Problem

$$P_f = k_3 \sinh^{-1} \left\{ CFUP_o - CFU_s \right\}$$

where:

P_f = the tactical force difference problem

k_3 = a constant currently equal to 1

$CFUP_o$ = the perceived tactical force utility of the opponent

CFU_s = own tactical force utility

Note: P_f is bounded so it can be no bigger than 1.0.

5d. Desired Land Value Problem

$$P_D = k_4 \cdot V \{ f_d - f_o \}, \text{ or } 0.0 \text{ whichever is larger.}$$

where:

P_D = the desired land problem

V = the value placed on the land in Subroutine DMFILE (Section 5.1)

f_d = the land fraction desired.

f_o = the land fraction actually occupied

k_4 = scaling coefficient

5e. Total Weekly Local Problem

$$P \equiv P_t + P_M + P_f + P_D$$

5.4 Subroutine Bargaining Control (WEBARG)

Subroutine WEBARG does not itself change any data. Its function is to adapt the problem data computed by Subroutine PROREC (see Section 5.3) into a standard format for use by Subroutine ACBARG (see Section 5.10) which actually attempts to make bargains. Bargaining is attempted each week for the two bloc members of each of the thirteen land conflict regions, one at a time. Neutral Nation-Groups do not bargain in the TEMPER world. The eight actual problems of PROREC and the eight perceived problems of PROREC of the two Nation-Groups are arranged into two standard arrays for ACBARG.

If PROREC signals WEBARG that annual bloc leader bargaining is to take place, it selects the real bloc leader problems and the perceived bloc leader problems. WEBARG in turn signals ACBARG that annual bloc leader bargaining is to be attempted. These two different functions are shown graphically in Figure 5-10.

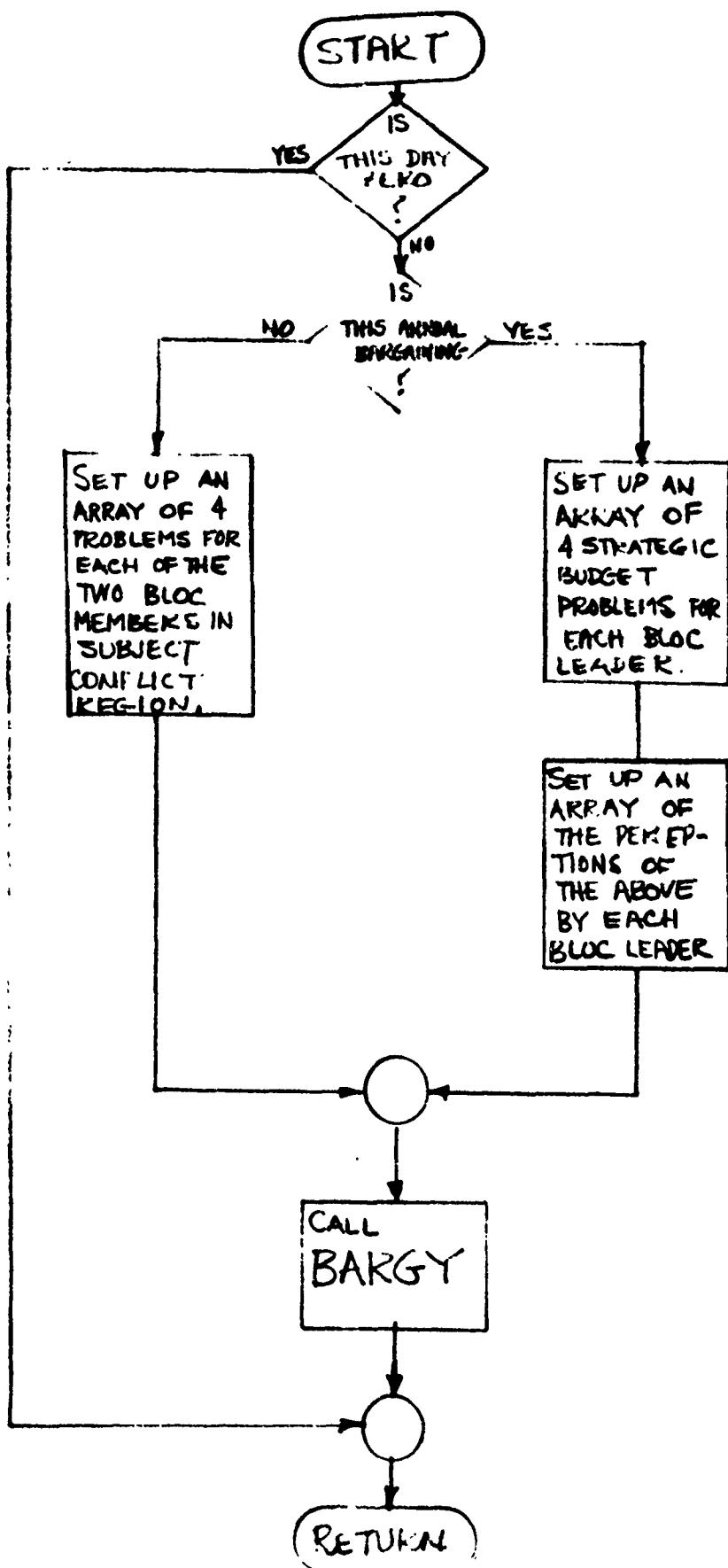


Figure 5-10 Flow Diagram of Subroutine WEBARG

5.5 Subroutine Bargaining (BARGY)

5.5.1 General Description of BARGY

BARGY is the bargaining subroutine. It deals with problems transmitted from the Bargaining Control Subroutine (WEBARG), attempts to form offers and requests,* and if successful, calls on Bargain Acceptance, (ACBARG), for implementation of the bargain.

Each week the Problem Recognition Subroutine (see Section 5.3) computes for each bloc member Nation-Group a set of four problems and a set of four perceptions of opponent problems concerned with:

- a. military operations
- b. deterrent threat levels
- c. tactical force difference
- d. desired land.

At the end of each year the accumulated bloc leader budget problems for defense, tactical forces, R&D, strategic forces, and the perceived problems of the opponent bloc leader are computed. All problems are expressed in dollars.

The paired problems and perceived problems are set into two arrays for BARGY by WEBARG for the two bloc members of each conflict region in turn.

The Bargaining Subroutine selects the problem of greatest magnitude from the array of problems and establishes the Nation-Group with this problem as the bargaining initiator. The largest perceived problem of the opponent Nation-Group is identified. The initiator Nation-Group calculates the reduction it must provide in the factor causing the opponent's problem to eliminate the opponent's problem as perceived (this becomes the offer) and the necessary reduction which the opponent must provide in the factor causing the initiator's problem to eliminate the initiator's problem (this becomes the request). These reductions form the offer-request pair.

* An offer is made by the bargaining initiator to reduce a quantity which he perceives is causing the opponent a problem, in return for a compensating act.

If the offer and request are acceptable to both Nation-Groups, BARGY continues by calling the Bargaining Acceptance Subroutine, ACBARG, described in Section 5.6. BARGY then eliminates from the array the problems which have been solved by this possible bargain and returns to consider the remaining less important problems. An offer or request is acceptable if acceptance does not cause a new problem to the acceptor.

5.5.2 Detailed Description of BARGY

BARGY performs the following:

- a. Select the most positive, i.e., largest problem. Identify the Nation-Group with it as the initiator, and the other Nation-Group as the opponent.
- b. If the problem is not greater than zero, return to WEBARG since there are no problems to bargain about. Otherwise, continue.
- c. Select the most positive opponent problem as perceived by the initiator.
- d. If it is not greater than zero (i.e., the opponent appears to have no problem needing solution), return to Step a and try the next smaller real problem. Otherwise, continue.
- e. Form initiator's tentative offer as equal to the perceived problem.*
- f. Form the request for opponent reduction equal to the real problem.
- g. The tentative offer is tested:
 1. If the initiator's problem of the type of the opponent's maximum problem is negative, i.e., the initiator has an excess, he can offer to reduce his excess to zero, or to reduce his opponent's problem to zero, whichever is smaller.

* Perceived defense spending problems of types 2, 3, or 4 are divided by the corresponding perceived power ratio motivation; and initiator types 2, 3, or 4 defense spending problems by the actual motivation. See Subroutine PROREC.

2. If the initiator has a positive problem of the same type as the opponent's maximum problem, he cannot offer to reduce that problem, unless by coincidence his maximum problem is the same type as the opponent's maximum problem. In that case, he offers to reduce by the amount of his problem, or his perception of the opponent's problem, whichever is smaller. Otherwise, he repeats Step d with the next smaller perceived opponent problem.

h. Opponent tests the offer:

If the opponent in fact has no problem, or if the offer does not eliminate his problem to zero, he will reject the offer. The initiator will consider the next smaller perceived problem and return to Step c. Otherwise, the offer is conditionally accepted.

i. Opponent tests the request:

If the opponent's problem of the initiator's maximum problem type is negative and if acceptance of the request does not cause the opponent a new problem, he will accept and Subroutine ACBARG is called to carry out the bargain.

If the opponent's problem is positive, he checks to see if the initiator has requested solution of a mutual problem in Step g.2. If so, he checks to see if the request leaves him an excess or zero problem. If so, the bargain is accepted and Subroutine ACBARG is called to carry out the bargain. If any of the tests fail, the initiator's problem is set to zero, and Step a is repeated for the next smaller real problem. This may cause the identity of the initiator and the opponent to reverse.

j. If ACBARG is called, the problems are considered solved except in the special case of tactical force reductions as described in Section 5.6. The problems and their perceptions are set to zero in the BARGY problem array, and Step a is repeated for the next smaller problem.

This process of forming and testing the offer and request is shown graphically in Figure 5-11. As noted above, certain problems (and their perceptions) are scaled by the desired Subroutine PROREC. (See Section 5.11) The figure assumes this scaling has occurred and that there is an excess to match each problem. The offer is made the lesser of the objective perception of the problem or the excess. If the scaled offer is less than the subjective view of the situation, the offer is rejected. If the request (which is either the initiator's view of the situation or a scaled view) is more than the opponent's excess, the request is rejected. If either the offer or the request is rejected, the bargain is not struck, and a new attempt is made as described above.

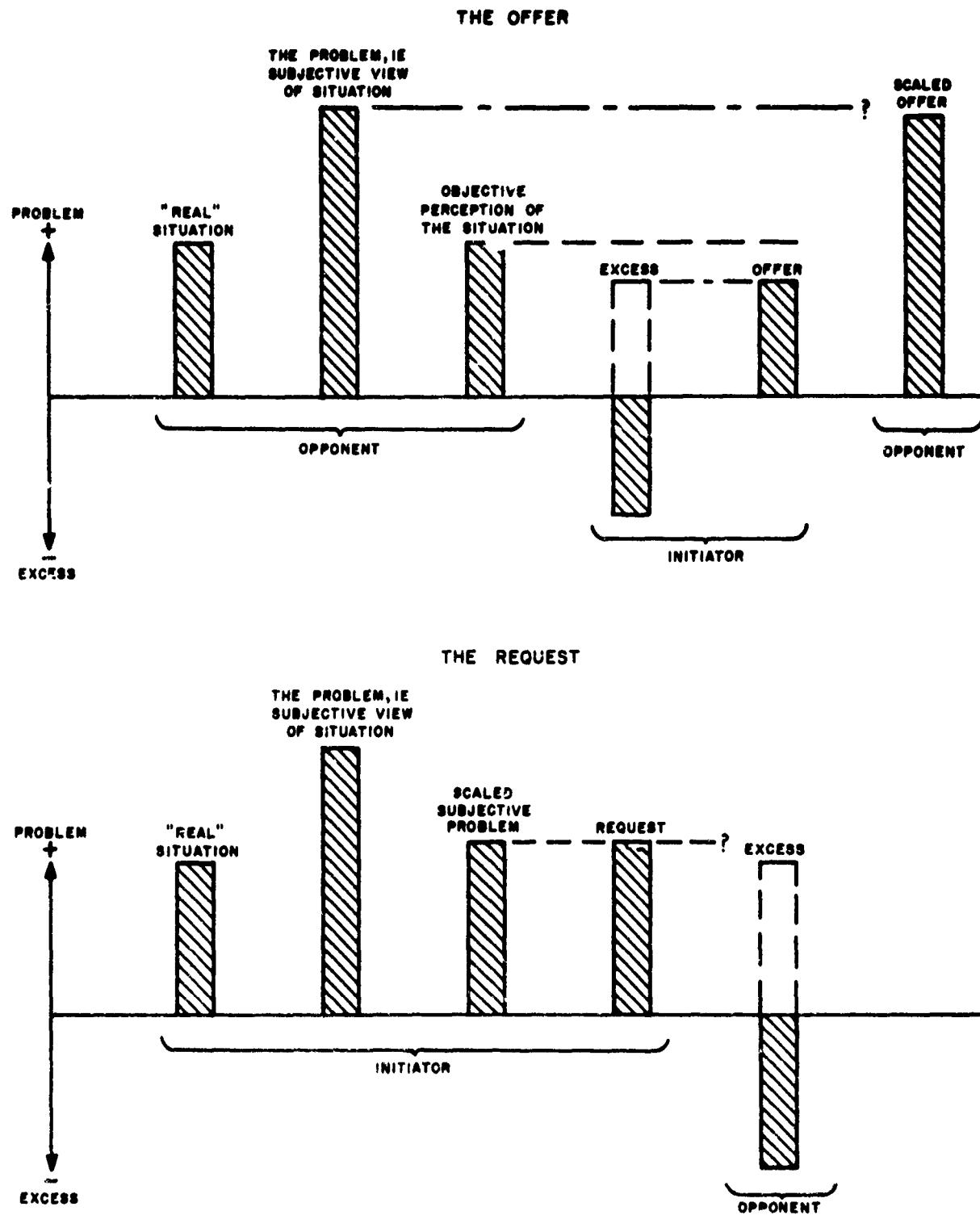


Figure 5-11 Elements of Bargaining

5.6 Subroutine Bargain Acceptance (ACBARG)

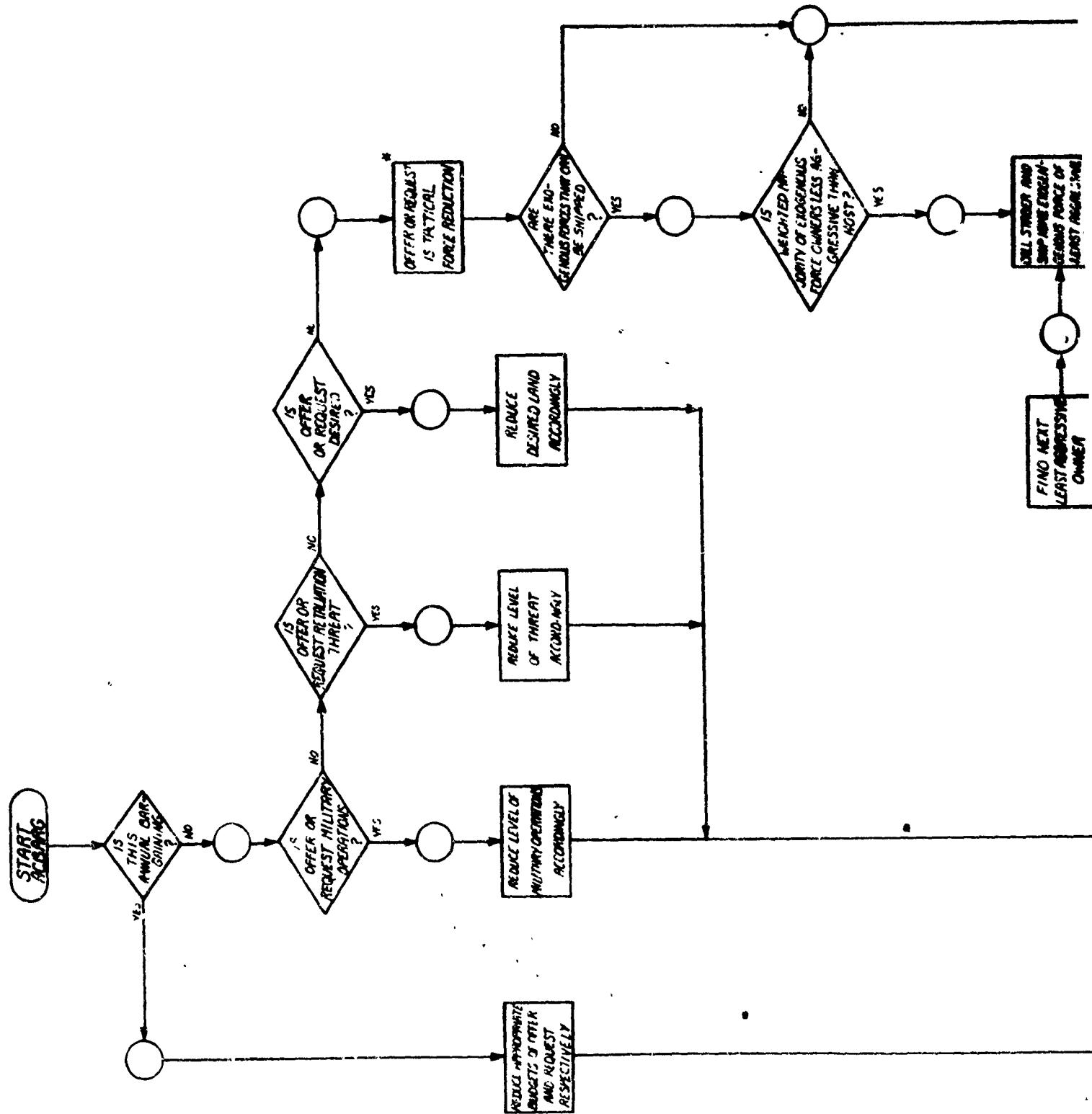
5.6.1 General Description of ACBARG

With the exception of tactical force reductions, the purpose of ACBARG is to implement each offer-request pair as it is established by Subroutine BARGY (see Section 5.5). This is accomplished by reducing, for each of the two Nation-Groups doing the bargaining, the quantities corresponding to the offer and the request. If the bargain calls for a tactical force reduction, the bargain can be implemented only if the Nation-Group which is to make the reduction is host to exogenous forces, the owners of which are in the main less aggressive than the host Nation-Group; otherwise, the bargain is rejected. This is shown in Figure 5-12.

When called by BARGY, ACBARG first determines if it is dealing with a bargain between the two bloc leaders. If it is, it uses a separate section of the subroutine to effect the appropriate reductions in the strategic budget problems of the two bloc leaders; these are the total military, the R&D, the strategic, and the conventional forces budget problems. The subroutine will identify which bloc leader is to fulfill the offer and the request respectively, and to which problem type each applies. The two problems (one for each bloc leader) are reduced by the amount of the offer and the request respectively. These need not be equal amounts. Subroutine BUDGET, which is described in Section 5.7, will use these four problems to establish the budgets of the strategic force owners, and so a reduction in one of the problems will tend to cause a corresponding reduction in the budget for the following year.

If the bargain is between two Nation-Groups on local problems, it is handled by the other portion of Subroutine ACBARG. There are four types of local problems as described in Section 5.3. These are:

- a. Conflict between the Subject Nation-Group's military operations and the opponent's threats to retaliate (called here the military operations problem).
- b. The discrepancy between the desired difference in tactical force utility between the Subject Nation-Group, and his opponent (called here the force ratio problem).



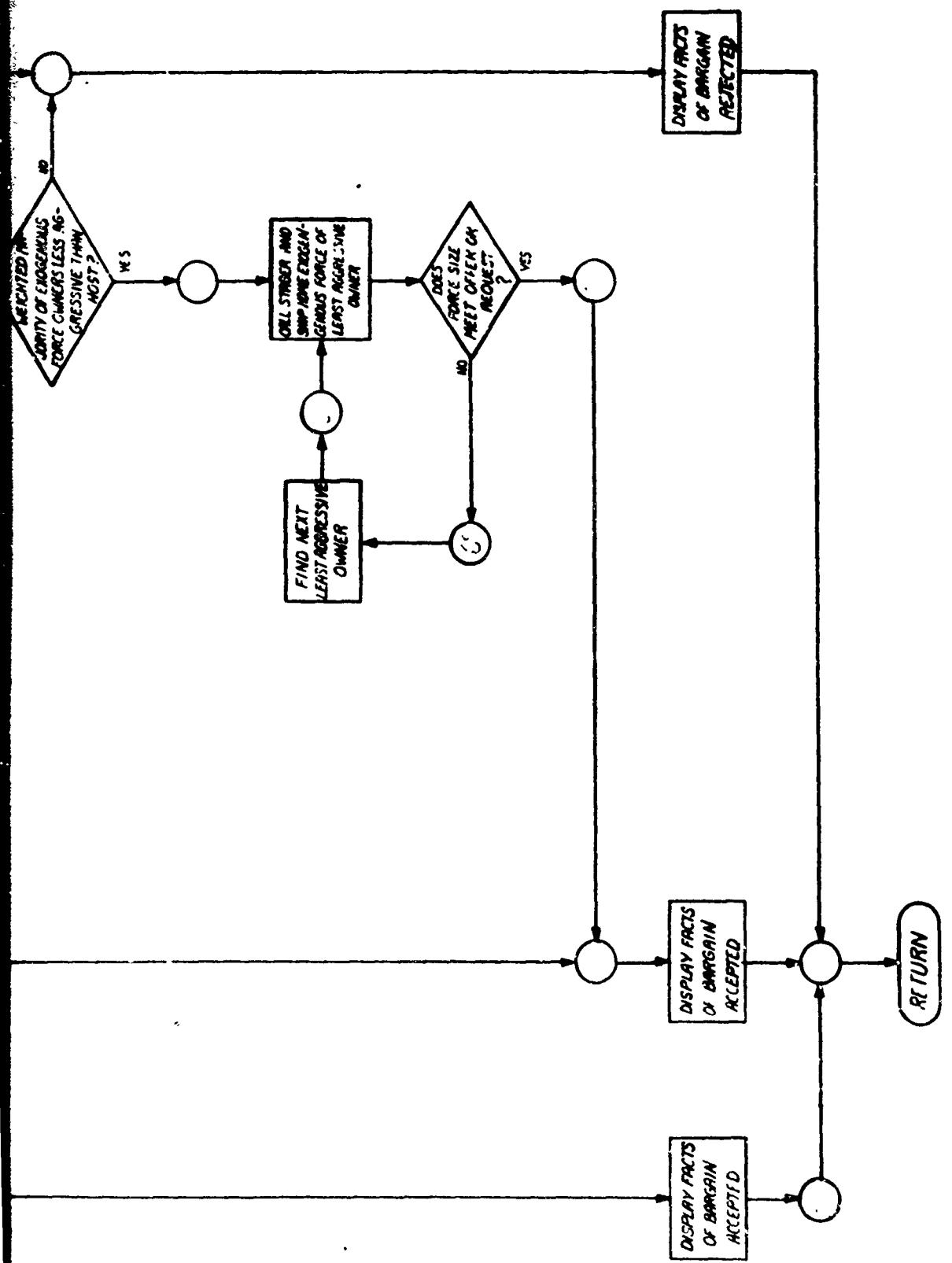


Figure 5-12 Simplified Flow Diagram of Subroutine ACBARG

c. Conflict between the subject Nation-Group's deterrent threat and the opponent's military operations (called here the threat problem).

d. The discrepancy between the fraction of the conflict region desired and the fraction owned (called here the desired land problem).

Each potential bargain consists of an offer by the initiating Nation-Group to reduce some factor which causes the opponent Nation-Group to have a problem, and a request by the initiator that the opponent reduce a factor which is causing the initiator to have a problem. These two problems need not be the same type. Subroutine ACBARG identifies the initiator and opponent Nation-Groups, and the size and type of the offer and request.

In the case of military operations, threat, and desired land problems, the amount of the offer or request is subtracted from the total problem of the Nation-Group. The amount of the offer or request is then converted into the units of the factor causing the problem and subtracted from that factor of the Nation-Group causing the problem. These two steps can be seen to both reduce the cause of the problem and so the size of the problem. The group of subroutines, WEBARG - BARGY - ACBARG, have as their purpose simulating such real world quid pro quo situations.

If the offer or request calls for a reduction in tactical forces, ACBARG does so by shipping exogenous forces home; otherwise, the offer-request pair is rejected and control returns to BARGY. If the Nation-Group which offers or is requested to reduce tactical forces is host to exogenous forces, it polls each of the ally Nation-Groups which owns exogenous forces in the host Nation-Group. In effect, each ally* is given votes equal to the product of its military coercion motivation, and the ratio of its force utility to the total exogenous force utility. The allies whose military coercion motivation is lower than the host are assumed to vote in favor of the force reduction; the allies with a higher level of military coercion motivation are assumed to vote against the reduction. The host is given votes equal to his own military coercion motivation. If the host has more votes than the total ally votes, he automatically

*In this paragraph "ally" is taken to mean just those allies who have supplied exogenous forces to the host Nation-Group.

accepts the bargain. Failing that, if the affirmative ally votes outnumber the negative ally votes, the bargain is accepted. If neither is the case, the host sums the alignment value points he has awarded to the allies voting affirmatively, and to those voting negatively. If the affirmative sum is the larger of the two, the bargain is accepted.

In this case, ACBARG uses Subroutine STAGER (see Section 4.3) to redeploy the forces. Exogenous forces are returned to the owner allies in order of level of military coercion motivation. The entire force of the ally with the lowest level is shipped back first, followed by the entire force of the next higher level and so on. This process continues until either the offered or requested reduction has been achieved, or all the forces of the allies voting affirmatively have been shipped home. If ACBARG finds that only a portion of an exogenous force deployment need be returned to satisfy the bargain, it will return only that portion and leave the balance in place.

Note that the reduction agreed to can only take place if there are adequate exogenous forces which qualify as described above. Otherwise, a smaller amount, possibly zero, will be shipped out, and in effect, the Nation-Group will not have lived up to the bargain. However, in the following weeks the opponent Nation-Group would likely perceive that it had an unfavorable tactical force ratio and would seek relief both through delivery of exogenous forces from its allies and new procurement. Furthermore, the first Nation-Group would tend to see its tactical force ratio problem as diminished and might tend to give up additional forces. These actions would tend to restore the balance. The TEMPER simulation, however, does not record the fact that one Nation-Group failed to live up to its agreement.

5.6.2 Detailed Description of ACBARG

ACBARG is called by BARGY each time an offer-request pair is ready for processing. ACBARG is supplied with the following information:

The conflict region
The initiator Nation-Group bloc
The opponent Nation-Group bloc
The size of the offer
The offer problem type
The size of the request
The request problem type

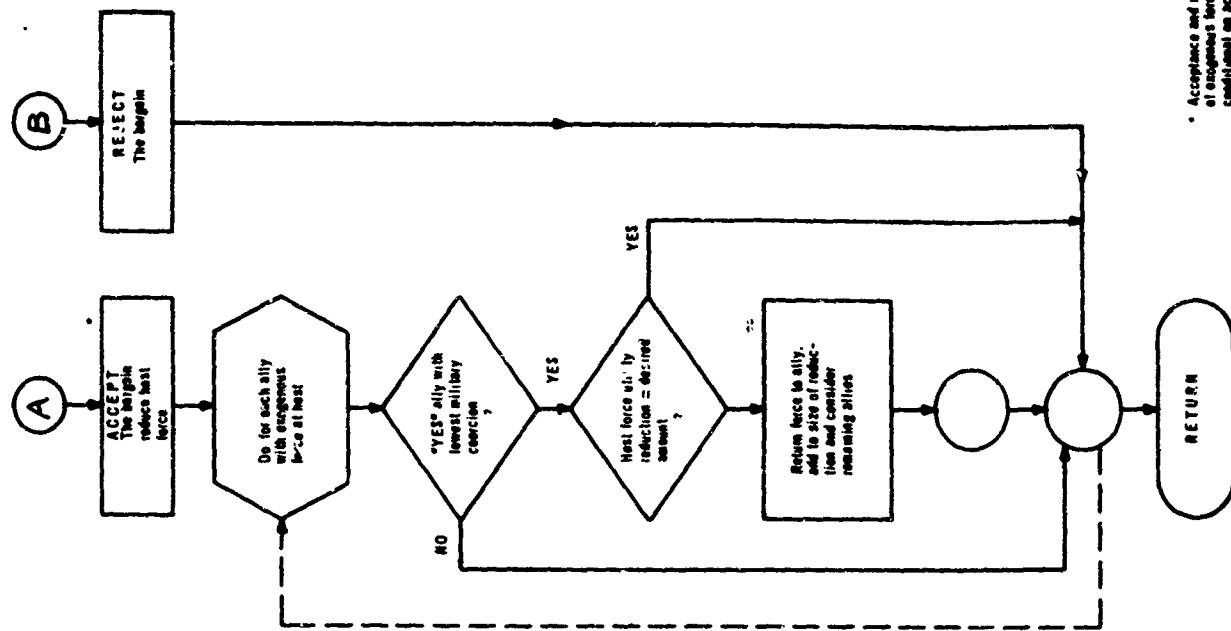
ACBARG computes separately the size of the problem reduction for the offer and for the request. In each case, it correctly identifies the subject Nation-Group, that is the one which is to undertake the reduction, as the initiator in the case of the offer, and the opponent in the case of the request. In each case, the offer or request is converted into the form of the problem cause. For example, the military operations problem is proportional to the hyperbolic tangent of the military operations level. See Equation (5b) of Section 5.3. Since the offer or request is in the same form as the problem, the inverse hyperbolic tangent is taken to find the reduction. The reduction is then subtracted from the problem cause. See Equation 1 for details.

When the problem to be reduced is reduction of tactical forces, ACBARG performs two functions which are not otherwise performed. These are consultation with allies providing forces to the subject Nation-Group, and return of the forces if the allies will accept the bargain. These functions are performed as shown in Figure 5-13 and described below.

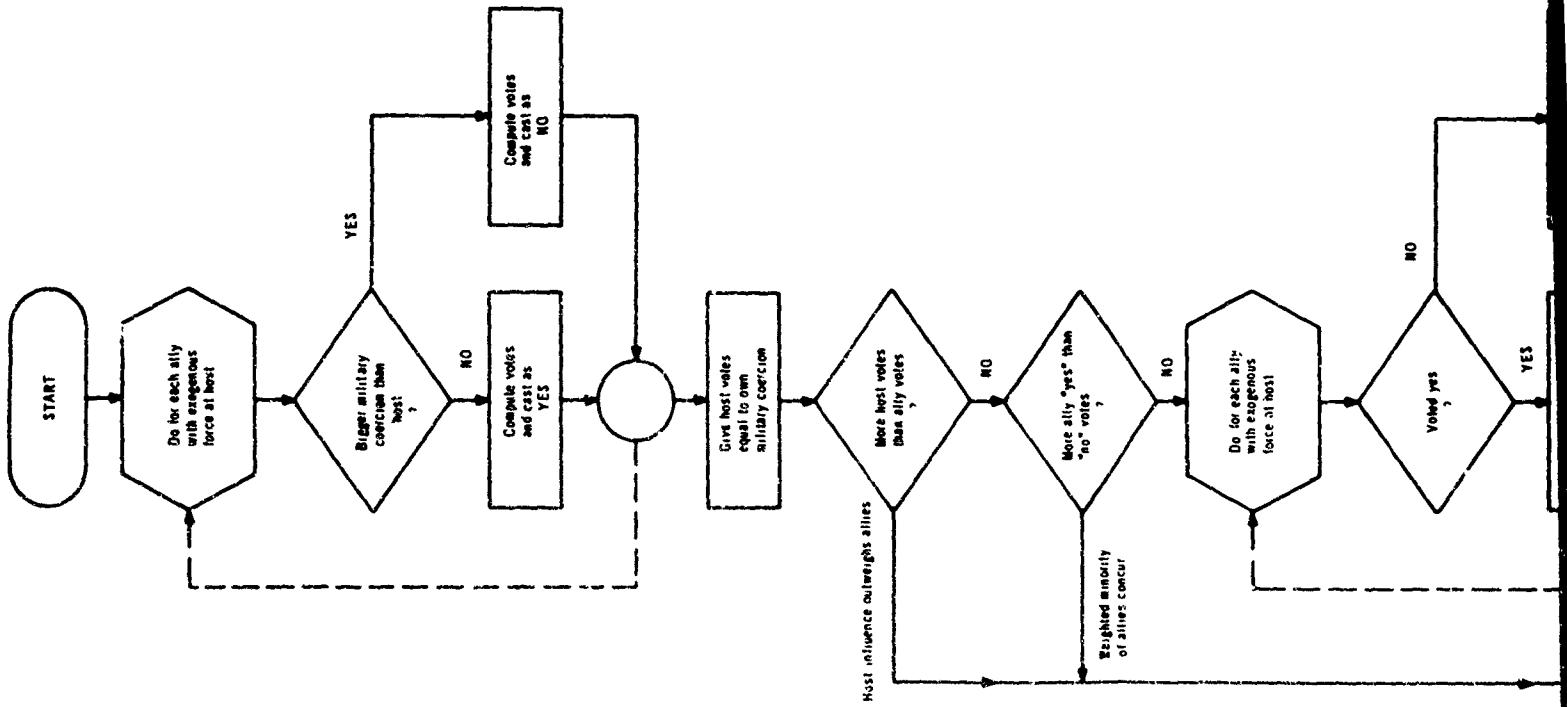
Part One - Poll Allies for Bargain Acceptance

Find the indigenous CFU by subtracting the total exogenous forces present in the Subject Nation-Group. If there is no exogenous force utility, reject the bargain and return to Subroutine BARGY.

Find the weighted military coercion (or "votes") for each ally as the product of his fraction of the exogenous CFU, and his level of military coercion motivation. Find the sum of these products for all allies, i.e., the "total ally votes".



- Acceptance and return of engagement letters is conditional on acceptance of the other half of the after-request price.



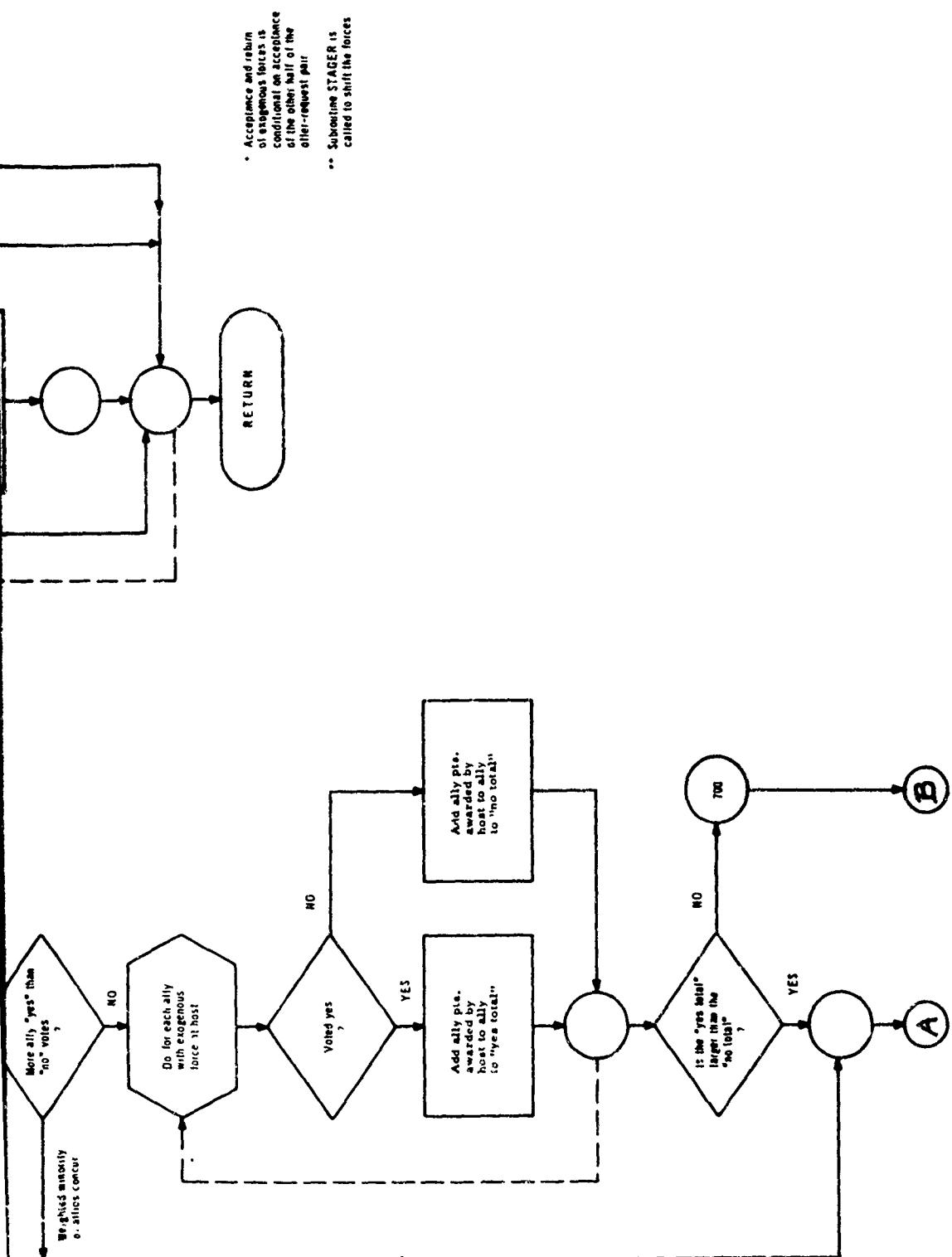


Figure 5-1-3 Implementation of Offer of Request to Reduce Tactical Force Utility by Subroutine ACBARG

Compute the sum of "votes" for those allies having military coercions less than or equal to the Subject Nation-Group, and the sum of the CFU furnished by these allies. (These are called the YES allies below.)

If the total weighted ally coercion ("total YES votes") is less than or equal to the military coercion motivation of the Subject Nation-Group, the bargain is accepted.

If the YES weight ("votes") is greater than half the total ally weight, the bargain is accepted.

Compare the total of the ally values awarded to the YES allies (called here the YES sum) and to the NO allies (called here the NO sum) by the subject Nation-Group.

If the NO sum is greater, reject the bargain to appease the more highly regarded allies, and return to Subroutine BARGY.

Otherwise store the amount of force to be returned for use in Part Two.

Part Two - Remove Ally Forces

Identify the exogenous force owned by the YES ally with the lowest military coercion motivation level.

Compare CFU of bargain, the amount of force to be returned, with the CFU of the YES ally's exogenous force.

Set the amount of CFU to be shipped, equal to either the total amount to be shipped or the amount of the YES ally's exogenous force being considered, whichever is smaller. Subtract the amount to be shipped from the total still to be shipped.

Call Subroutine ST'AGER (see Section 4.3) to remove the force from the subject Nation-Group and to place it in the force inventory of the owning ally. If the amount of force to be returned was smaller than the YES ally's exogenous force, the excess amount of the force will remain deployed in the subject Nation-Group.

Remove the force from the list of YES ally forces available for return

If the revised amount of force to be returned is greater than zero, go to the first step above and repeat.

5.6.3 Equations in ACBARG

Military Operations Level Reduction

$$1a. \quad R = \tanh^{-1}(A)$$

Deterrent Threat Level Reduction

$$1b. \quad R = \tanh^{-1}(A)$$

Tactical Forces Reduction

$$1c. \quad R = \min \left\{ \sinh(A), \text{ or } \sum \left(\begin{array}{l} \text{Concurring} \\ \text{Ally Forces} \end{array} \right) \right\}$$

Desired Land Fraction Reduction

$$1d. \quad R = \frac{A}{k_4 \cdot V}$$

where:

R = the amount by which the problem cause is to be reduced

A = the size of the offer or request

k_4 = a constant, see Section 5.3.3

V = land value

Note: Bloc leader's budget problems are expressed directly in budget amounts, so that reduction and the offer or request are equal. The size of the offer or request is set according to the logic described in Section 5.5, and shown graphically in Figure 5-11. and is equal either to a problem or a perceived problem. Subroutine PROREC (Section 5.3) computes problems as a function of problem causes. Subroutine ACBARG uses the corresponding inverse function in computing the reduction based on the offer or request amount.

5.7 Subroutine Budget Makeup (BUDGET)

5.7.1 General Description of BUDGET

BUDGET is the routine which takes the past year's defense budget problems, which have been accumulated by PROREC (see Section 5.3) for each Nation-Group and acted upon by budget bargaining (see Section 3.4) and sets the government budget for R&D, strategic forces, and tactical forces spending. The budget is transmitted to the Economic Submodel (see Chapter 4) for use during the next year in procurement and maintenance of forces.

The BUDGET Subroutine receives a set of four discrepancies between actual and needed military spending from the Problem Recognition Subroutine (PROREC). These discrepancies are formed as a result of the threat felt by each Nation-Group at the end of each quarter. GNP is projected for the next year using the past year's GNP growth, and an approximation to the next year's government funding is calculated using the current tax rate for the next quarter.

The defense requirement for new funds is formed by adding past year's discrepancy between the past "ideal" funding and the actual funding, to the past funded level. The discrepancy may be positive implying too few funds were available last year to cover the defense need, or it might be negative implying a more peaceful world and indicating excess funds were available and recommending a budget cut. The desired defense budget or fraction of government funds spent on defense is formed by dividing the requirements by the projected government spending.

If the subject Nation-Group is a strategic force owner, distribution of the defense funds is made between R&D, strategic forces, and tactical forces. A discrepancy between "ideal" needs and real funds has been computed for all three during the past year by Subroutine PROREC, and is added to the projection of the past year spending to obtain the "need". The three "needs" may exceed the amount of new funds available in which case the total allocation is in proportion to the R&D and strategic fractions of the defense funds. The tactical force fraction is the remaining portion of defense funds.

5.7.2 Functions of BUDGET

The functions of BUDGET are described below and shown graphically in Figure 5-14.

BUDGET is designed to display the details of unusual economic growth or balance of payments. If annual growth rate is less than one and one-half percent or greater than five percent, the facts are displayed. If the balance of payments is favorable and greater than one and one-half percent of annual GNP, the amount is displayed. If desired, both of these functions can be suppressed by the user.

BUDGET next computes the desired military spending fraction of the total government budget, for each Nation-Group. The desired military fraction is either (a) the defense spending motivation set by Subroutine KULTUR (see Section 2.4), or (b) the previous fraction plus the yearly defense spending problem (both scaled by economic growth and change in tax rate, whichever is smaller). This is shown in Equation (1).

If the Nation-Group is a strategic force owner, BUDGET computes the desired fraction of the military budget for R&D, conventional forces, and strategic forces, as shown in Equation (2).

5.7.3 Equations in BUDGET

Military Spending Fraction

$$1. \quad f_M = \min \frac{M_M}{10}, \text{ or } \max \left(\frac{f_M \cdot GNP' \cdot R_T' + P_M}{R_T \cdot GNP' (1 + R_G)} \right), \text{ or } 0.01$$

"min" means take the smaller quantity.

"max" means take the larger quantity.

where:

f_M = the desired military spending fraction

M_M = the military spending motivation as set by Subroutine KULTUR

f_M' = the value of f_M during the previous year

GNP' = the annual GNP of the previous year

R_T' = the average tax rate of the previous year

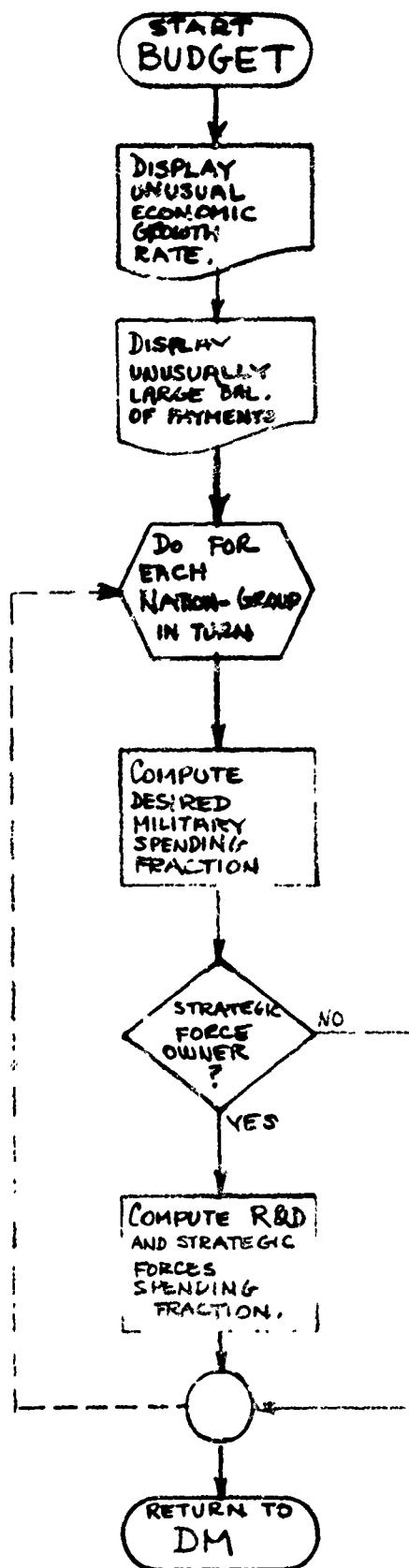


Figure 5-14 Simplified Flow Diagram of Subroutine BUDGET

P_M = the military spending problem computed by
Subroutine PROREC

R_T = the current tax rate motivation

R_G = the annual growth rate set by Subroutine PDCNTL

Note that the numerator is the sum of previous military spending plus the spending problem, or an estimate of the desired spending, and the denominator is an estimate of the total government spending. The ratio of the two is then the desired fraction. The computer program is designed so that in any event f_M is never less than 1 percent or $M_M/10$.

R&D Fraction of Military Spending

2a. $f_{MR} = f_{MR}' \left(\frac{f_M' \cdot GNP' \cdot R_T' + P_R}{f_M \cdot GNP' \cdot R_T + P_R + P_S + P_C} \right)$

Strategic Forces Fraction of Military Spending

2b. $f_{MS} = f_{MS}' \left(\frac{f_M' \cdot GNP' \cdot R_T' + P_S}{f_M \cdot GNP' \cdot R_T + P_R + P_S + P_C} \right)$

Conventional Forces Fraction of Military Spending

$$f_{MC} = f_M - f_{MR} - f_{MS}$$

where:

f_{MR} = the desired research fraction

f_{MR}' = the previous year's fraction

f_{MS} = the desired strategic forces fraction

f_{MS}' = the previous year's fraction

f_{MC} = the conventional forces fraction

P_R = the research spending problem

P_S = the strategic forces spending problem

P_C = the conventional forces spending problem

5.8 Subroutine Command Allocation (CDALC)

5.8.1 General Description of CDALC

Given problems, TEMPER will form cold war decisions on the escalation or de-escalation of military operations and the level of deterrent threat to issue and examine the probability of accidental initiation of nuclear war. In time of war, decision will be made on the level of military operations and whether or not to release tactical nuclear weapons for use. If both sides determine that their losses exceed their gains and enthusiasm for the war, then the war will be terminated. In carrying on these functions, the following order is observed.

- a. War conduct and termination
- b. Cold war operations
- c. Accidental nuclear initiation

5.8.2 Detailed Description of CDALC

A feeling of the disutility of the war is simulated by summing the size of the problem, the total losses in the war to date, the cost of the military force committed, and the propensity to use force together with the enemy advantage as a function of the difference between the level of military operations of the two sides (See Equation 1). The model assumes that both sides will increase their levels of operations during the first month after which a change will be a function of how rapidly the disutility changes. The more the war hurts, i.e., the faster disutility increases, the more will be the escalation of the level of military operations (See Equation 2). Since an increased level of military operations will result (see SHIFT) in a higher desire for forces, we can expect the tempo of a war to increase as long as military resource is available to supply the desire of nations to prosecute the war. In the TEMPER world, winning and losing are separated from and not included in disutility. If both sides perceive that their losses are greater than their gains and zeal for war (See Equation 3), instead of increasing disutility and

therefore increasing the pace of the war, both sides will terminate. As zeal increases, it tends to outweigh net losses. Zeal decays over time but increases as losses increase (See Equation 4).

Nuclear Army Divisions are normally considered to be as effective as ROAD divisions. In a war, if there is a very high level of military operations, and if there are nuclear army divisions deployed to the area, the owner will release the weapons for use, thereby enhancing the kill capability of those forces.

In a cold war situation, TEMPER determines crisis as a function of the rate of problem change (See Equation 5). Distortion in crisis is simulated by magnifying the problem (in LIANCE).

In the case of crisis, the maximum change in the deterrent threat level and military operations level is assumed applicable if WINIT recommends escalation or de-escalation. If there is no threat, then the maximum change is scaled to the cube root of the problem. (See Equations 6 and 7.)

As the relations between nations become more tense, the probability of accidental initiation of nuclear war increases. TEMPER computes this probability, and if it is above 0.5 uses a random number to determine whether or not to print out a warning to the analyst (See Equation 8).

5.8.3 Equations in CDALC

1. Disutility = Problem Size + K_1 (Total Loss to Side) + K_2

(Quarterly Operating Cost of Forces) + K_3 (Propensity to use Force) (Opponent's Superior Level of Military Operations)

2. Change in Military Operations^{*} = K (Smoothed Disutility - Disutility) ± 1

where:

$$\left(\begin{array}{c} \text{This Week's} \\ \text{Smoothed Disutility} \end{array} \right) = \frac{\text{Last Week's Smoothed Disutility} + \text{Utility}}{2}$$

± 1 shows whether last week was increase (+) or decrease (-)

* Changes in deterrent threat are figured in the same way. Only the constant K is changed.

3. If Gain + Zeal - Total Loss = Negative Continue War

where

Gain = (Advance) x (Value of Land Taken or Lost)

Total Loss = Cost of Procuring Force Lost

4.
$$\text{Zeal} = \left[e^{-\left(\frac{\text{Length of War}}{K_1} \right)} \right] (\text{Propensity to Wage War}) K$$
$$\left[1 + K \left\{ 1 - e^{-\left(\frac{\text{Total Loss}}{\text{Annual GNP}} \right)} \right\} \right]$$

5. There is crisis if:

$$\frac{\text{This Week's Problem}}{\text{Last Week's Problem}} + 0.1 K$$

where

K is a crisis threshold for rate of problem change

6. Increased level of military operations =

$$K (\text{escalation intensity}) Q$$

where:

K is the maximum increase for escalation under crisis or when faced with a problem (0.05 in current Data Base)

Escalation intensity is

$$\sqrt[3]{\text{PROBLEM SIZE}} \quad \text{if there is a problem}$$

$$1.0 \quad \text{if there is a crisis}$$

and Q is the direction of change (escalate or de-escalate or status quo) supplied by WINIT

7. Increased level of deterrent threat = $K_p (\text{escalation intensity}) Q_p$

where:

K_p is the maximum increase for escalation under crisis or when faced with a problem, (1.0 in the current data base.)

Escalation intensity is

$3 \sqrt{\text{PROBLEM SIZE}}$ if there is a problem

1.0 if there is a crisis

and Q_p is the direction of the change (escalate or de-escalate or status quo) supplied by WINIT

8. Print warning if:

Random Number < Probability of Nuclear Initiation

where:

Random Number is from an evenly distributed series

Probability of Nuclear Initiation > 0.5

5. 9 Subroutine War Initiation (WINIT)

5. 9.1 General Description of WINIT

WINIT is called to determine for a Nation-Group if it should escalate, de-escalate, or maintain the status quo. WINIT assesses the desirability of increasing or lowering the Nation-Group's level of military operations (escalation or de-escalation). It further checks the advantages of raising or lowering the deterrent threat level (the allowable threshold of opponent military operations). The factors used in evaluating changes in these include potential costs, losses, gains, and risks. WINIT returns its recommendations to CDALC by setting two "flags", one for military operations and one for deterrent threat. Values of +1, 0, and -1 represent escalation, no change, and de-escalation respectively. In summary, WINIT simulates the process by which the Nation-Group leadership evaluates the potential gains and losses in its conflicts with the opponent Nation-Group and decides on its course of action.

WINIT has two main functions. One is to assess the desirability of escalation or de-escalation in level of military operations and the second is to assess the desirability of escalation or de-escalation in deterrent threat level. Deterrent threat level defines the maximum tolerable level of military operations by the opposing Nation-Group. WINIT is called from CDALC (Command Allocation Subroutine) for each problem or crisis.

In assessing risks, values are first calculated for the quantities following for the subject Nation-Group:

- a. potential gain in territory by escalating
- b. potential loss in territory by escalating
- c. probability of winning a conventional war
- d. potential loss due to a nuclear initiation in retaliation
- e. probability that a conventional war will occur
- f. threshold of (minimum) calculated utility which must be obtained to escalate military operations

g. a random number between 0-1

These quantities are established as follows:

a. The difference between the territory desired and the territory held, provided this exceeds zero; otherwise, it equals zero.

b. This is the same function of the opponents perceived desire for land less what he owns. In other words, these are the largest possible fractions of the conflict region that the Nation-Group could either win or lose. Each can range from 0 to 1.

c. The probability of winning a war is computed as a function of the difference in total CFU and that possessed by the opponent in the conflict region, and of the difference in total and opponent CFU possessed throughout the world. If the pair of bloc members in each conflict region had equal forces, both the global difference in tactical forces and the local difference would be zero, and the probability of winning would be 0.5. As a given block increases its relative superiority, the probability of its members winning also increase, but a member of the inferior bloc will have a high win probability if he has a high local superiority.

d. The most complicated of the functions calculated is the nuclear escalation risk value. This function is a multiple of terms as follows:

1. The probability of deterrent threat failure, evaluated using the Beta Function.

2. The potential percentage population loss to be incurred by the subject Nation-Group if the opponent bloc attacks. It is computed by Subroutine STDRM.

3. A general deterrent threat credibility number set by the user for each Nation-Group.

4. A function of the deterrent threat problem which estimates the effect of the perception of the opponent's maximum tolerable level of military operations.

e. The probability that a conventional war will occur is an exponential function of opponent deterrent threat level and own level of military operations.

f. A minimum gain or utility threshold is set as a linear function of the subject Nation-Group's propensity to employ military coercion. As it rises, the threshold rises to simulate the greater willingness to gamble on the consequences of using military force.

Once these values have been obtained, a function (utility of gain) is calculated as the sum of the following terms:

a. Probable gain in land value (the product of land value, possible gain, and win probability) less the following terms.

b. Probable loss in land value (the product of the value of own land, the possible loss, and the loss probability).

c. Probable loss from nuclear attack.

d. Probable loss from conventional attack.

e. Minimum gain threshold.

f. A random factor.

The results of the above calculation are interpreted as tabulated below:

- a. (utility of gain) > 0; escalate; set military operations flag = +1
- b. (utility of gain) < 0, but less than the threshold: maintain status quo; set the flag = 0.
- c. (utility of gain < 0, and larger in magnitude than the threshold de-escalate; set the flag = -1.

Deterrent threat establishes the perceived level of military operations by the opponent Nation-Group at which the subject Nation-Group has a problem. When the subject Nation-Group sets its deterrent threat to a certain value, it is asserting that nuclear retaliation is likely if the opponent sets his military operations level to a value greater than 10 less the level of the deterrent threat. If threat is 10, no military operations will be tolerated; if threat is 0, any level of military operations will be tolerated.

WINIT recommends escalation, de-escalation, or no change in deterrent threat. An escalation brings a higher risk due to the increased probability of nuclear war, but the higher threat level may help the Nation-Group to accomplish some objective. In setting the deterrent threat level, the two effects are considered and the alternative with highest net gain is selected.

WINIT makes its final decision according to the value of an overall utility of threat escalation as tabulated below:

- a. If utility is greater than a threshold value, escalate, set threat flag = 1.
- b. If magnitude of utility is less than the threshold, maintain the status quo; set threat flag = 0.
- c. If the utility is negative and greater in magnitude than the threshold, de-escalate; set threat flag = -1.

The threat escalation utility is a function of the subject Nation-Group's local problem size as set by Subroutine PROREC, an estimate of opponent's estimate of the probability of nuclear attack, the problem caused by the opponent's military operations, and is an inverse function of the potential nuclear war loss of the opponent should the subject Nation-Group preempt.

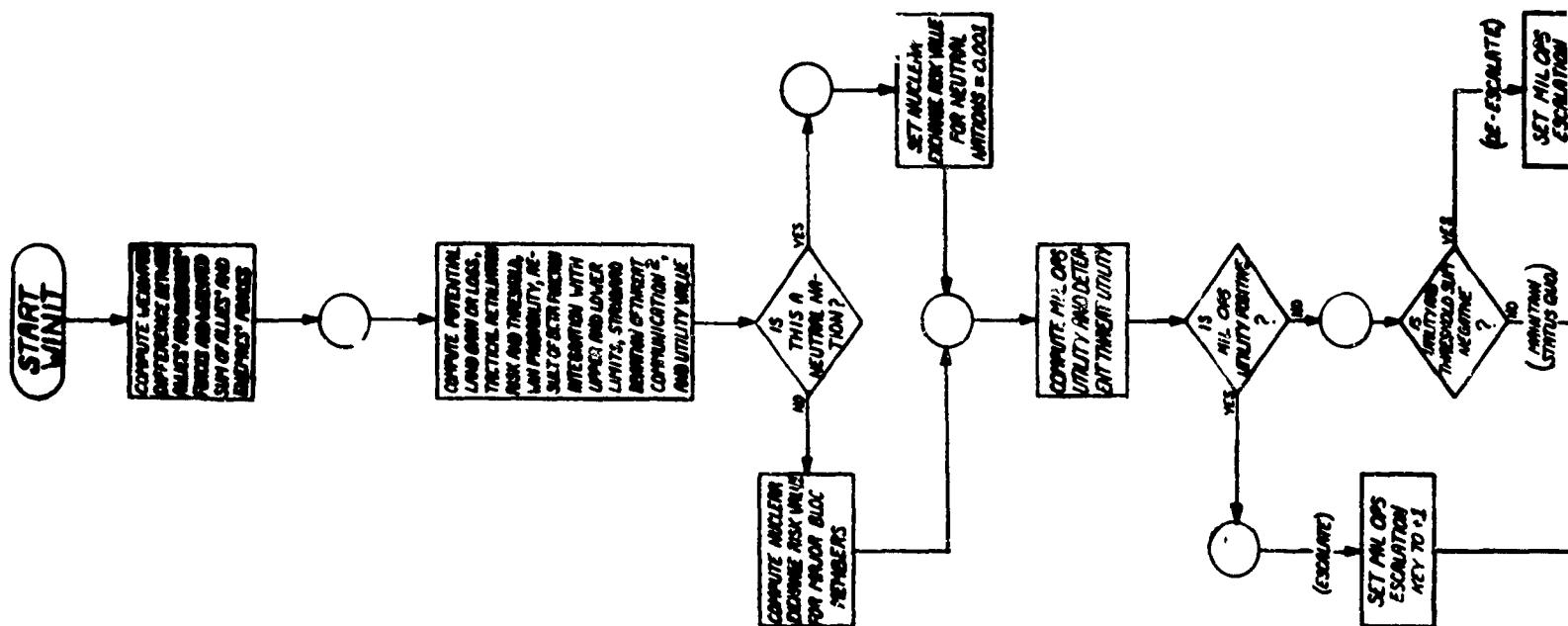
5. 9.2 Detailed Description of WINIT

WINIT is called for each Nation-Group problem or crisis. See Figure 5-15, a simplified flow diagram.

WINIT first determines risks of escalation of military operations as follows:

- a. The potential territorial gain is calculated as the difference between the desired territory and actual territory held within the conflict region. If this is negative, it is set back to zero. See Equation 1a.
- b. The potential territorial loss is computed as the difference between the perceived desired holding of the opponent and his actual holding. See Equation 1b.
- c. The tactical retaliation risk, the estimate of the threatened retaliation problem is given in Equation 1c.
- d. A threshold is computed as a function of two parameters, and the military coercion motivation of the subject Nation-Group. See Equation 1d.
- e. The probability of win is estimated as one-half + one-half the hyperbolic tangent (A) where A is the difference between the total counterforce utility in the world for both blocs and this conflict region divided by the sum of "total CFU in the world" and in this bloc scaled by a parameter. See Equation 1e.

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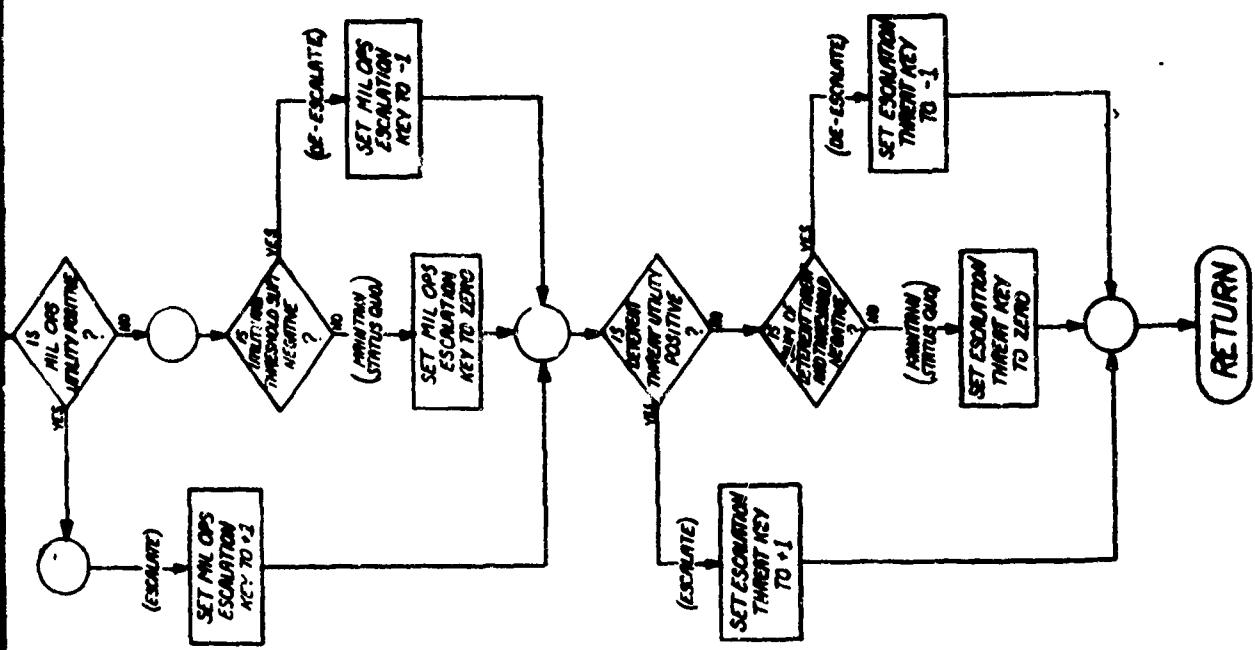


Figure 5-15 Simplified Flow Diagram of Subroutine WINIT

limit

f. The Beta Function, $\int_0^P (1 - x)^Q$, is evaluated using the three arguments as shown in Equation 2, and listed below:

1. Ratio of enemy's possible gain to his possible loss due to attack, A_1 , is the product of two terms:

(a) The weekly problem size of the subject Nation-Group.

(b) The ratio of opponent bloc population surviving a nuclear attack initiated by the subject.

This is the integration limit of Beta Function.

2. Probability that the enemy expects to be attacked,

A_2 ; A_2 equals one plus the hyperbolic tangent (Q) scaled by one half the retaliation credibility where the Q is the perceived opponent military operations level plus the subject Nation-Group deterrent threat level minus 10, and divided by a scaling factor.

3. The square of the standard deviation in threat communication, A_3 , a parameter.

g. The risk of a nuclear exchange is computed for West and East. This is a product of the following terms:

1. The Beta Function; See Equation 3.

2. The expected percentage population loss in the subject bloc, if the opponent preempts.

3. The credibility the opponent bloc places on the threat.

4. A scaling constant.

5. A function which translates the perceived deterrent threat level into an attack probability.

This is shown in Equation 4.

h. The utility of military operations escalation by the troubled Nation-Group is the sum of six terms.

1. The product of probability of win times opponent's land value times the potential gain.
2. The negative product of potential loss times own land value, times one minus win probability.
3. The negative of the nuclear risk.
4. The negative of the tactical retaliation risk.
5. The negative of the threshold.
6. A probabilistic term: A weighting parameter times a random number chosen between + 0.25 and - 0.25.

See Equation 5.

i. The Escalation Key is set as follows:

1. Escalation: Key = 1 if the utility (Step 8) is ≥ 0 .
2. De-escalation: Key = -1 if the utility is less than the negative of the threshold.
3. Do nothing: Key = 0 if the utility is between the negative of the threshold and zero.

The deterrent threat is now considered:

a. Total expected gain if a deterrent threat is made is the weekly problem of the subject Nation-Group times the sum of the following terms:

1. 1.2 minus a random number ranging from -0.2 to +0.2.
2. The Beta Function value times probability that the enemy expects to be attacked, A_2 in Step 6b. above, divided by the enemy's potential value loss, A_1 in 6a above.

See Equation 6.

b. The threat key is set as follows:

1. If the utility exceeds the attack utility threshold, retaliation level escalation is recommended (Key = 1).
2. If the utility is less than minus the threshold, reduction in the retaliation level is recommended (Key = -1).
3. If the magnitude of the utility is less than the magnitude of the threshold, no change is recommended (Key = 0).

5.9.3 Equations in WINIT

1a Potential territorial gain.

$$P_g = f_d - f_n, \text{ but not less than zero.}$$

where:

P_g = potential land fraction gain.

f_d = desired land fraction.

f_n = occupied land fraction

1b. Potential territorial loss.

$$P_l = pf_{do} - f_{no}$$

where:

P_l = potential territorial loss.

pf_{do} = perceived opponent desired land.

f_{no} = opponent occupied land fraction.

1c. Conventional War Initiation Risk

$$R_c = k_3 \cdot c_1 \cdot \exp \left\{ \frac{T_{op} + M_s - 10}{C_2} \right\}$$

where:

R_c = conventional war initiation risk.

k_3 , c_1 , and C_2 are constants.

\exp = epsilon exponentiated by the following term.

T_{op} = perceived level of opponent deterrent threat.

M_s = subject Nation-Group level of military operations.

1d. Military Operations Threshold

$$TH_m = k_4 \left\{ k_5 - MC_s \right\}$$

where:

TH_m = military operations level threshold of the subject Nation Group.

k_4 and k_5 are constants.

MC_s = the military coercion motivation of the subject Nation-Group.

1e. The probability of win

$$P_w = \left\{ \frac{1}{2} \cdot 1 + \tanh \left[\frac{CFU_s - CFU_{op} + \Delta CFU}{W_1 (CFU_s + CFU_{op} + \Sigma CFU)} \right] \right\}$$

where:

P_w = the probability of the subject Nation-Group winning a conventional war with the opponent.

CFU_s = the total tactical force utility of the subject Nation-Group.

CFU_{op} = the perceived total tactical force utility of the opponent.

ΔCFU = the difference in the total tactical force utilities of the two blocs.

ΣCFU = the sum of the total tactical force utilities of the two blocs.

2. Evaluation of the Beta Function

The Beta Function is defined as:

$$B(p, q) = \int_0^1 x^p (1 - x)^q dx$$

It is evaluated in the TEMPER simulation by dividing the integration interval into 50 equal segments in the form:

x = the segment number + 50

$$2a \quad p = \frac{A_2 (-1 - A_2)}{A_3}$$

$$2b \quad q = \frac{A_2 (-1 - A_2)}{A_3}$$

The Beta Function is evaluated as follows:

$$\beta = \frac{S_3 + (50 A_1 - 1) (S_1 - S_3)}{S_2}$$

where:

3

$$A_1 = P_s \cdot k_{wo} \left\{ \frac{1 - LOSS_{a-b}}{LOSS_{a-b}} \right\}$$

$$A_2 = \frac{1}{2} \left\{ 1 + \tanh \left(\frac{M_{op} + T_s - 10}{C_1} \right) \right\} \left\{ C_b \right\}$$

$$A_3 = L_3^2$$

$L = A_1$ truncated to an integer value.

$L + 1$

$$S_1 = \sum_{y=1}^{L+1} f(y)$$

L

$$S_2 = \sum_{y=1}^L f(y)$$

$y = 1$

L

$$S_3 = \sum_{y=1}^L f(y)$$

$y = 1$

$$f(y) = \left(\frac{y}{50} \right) P \left(1 - \frac{y}{50} \right) q$$

The variables and constants used above are as follows:

P_s = the local weekly problem of the subject Nation-Group

k_{wo} = is a constant which converts the population ratio to a commensurate dollar value.

$LOSS_{a-b}$ = the fraction of the opponent population lost when the subject Nation-Group preempts a nuclear exchange.

M_{op} = perceived level of opponent military operations.

T_s = subject Nation-Group's level of deterrent threat.

L_3 = Variance in threat communications currently set at 0.5

C_1 = is a constant currently set at 2.

$L = A_1$

4. Risk of Nuclear War Initiation

$$R_n = k_1 \cdot \beta \cdot C_o \cdot LOSS_{b-a} \left\{ 1 + \frac{1}{C_1} \tanh \left(M_{op} + T_s - 10 \right) \right\}$$

where:

R_n = the risk of nuclear war initiation

k_1 = a constant currently set at 10.0

β = the value of the Beta Function

C_o = the opponent threat credibility

$LOSS_{b-a}$ = the population loss fraction to the subject bloc if the opponent bloc should preempt.

M_{op} = the perceived level of opponent military operations.

T_s = the deterrent threat level of the subject Nation-Group.

C_1 = a constant currently set at 2.0.

5. Military Escalation Utility.

$$U_m = P_g \cdot V_{a-b} \cdot P_w + P_l \cdot V_{a-a} \cdot (1-P_w)$$

$$-R_n - R_c - TH_m - W_3 \cdot (N_r)$$

where:

U_m = the military escalation utility.

V_{a-b} = the value the subject Nation-Group puts on the opponent land.

V_{a-a} = the value the subject Nation-Group puts on its own land.

W_3 = a constant currently set at 0.5.

N_r = a uniformly distributed random number ranging from + 0.5 to - 0.5.

6. Deterrent Threat Utility

$$U_T + P_s \left\{ 1.2 - 0.4N_r \right\} + \beta \frac{A_2}{A_1}$$

where:

U_T = the deterrent threat utility.

5. 10 Subroutine Alliance Control (LIANCE)

5. 10. 1 General Description of LIANCE

The LIANCE Subroutine determines the consignments of aid list representing a willingness to supply to Nation-Groups (allies or neutrals) specific force levels (in counterforce utility) from exogenous and indigenous forces.

In performing its functions, LIANCE relies on two other subroutines, XLIANC and WINOVR.

LIANCE executes events in the following order:

1. Determine force needs, REQST (for allies) and REQSTN (for neutrals).
2. Identify the exogenous forces which may be shipped from excesses.
3. Select first ten requests to be dealt with by each bloc.
4. Set variables to be used in XLIANC, including the subject Nation-Group, fraction of bloc GNP represented by subject Nation-Groups, the amount of request for counterforce utility, and the level of need or problem, i. e., to help a war, crisis, or problem.
5. Call Subroutine XLIANC to determine for each bloc Nation-Groups' willingness and ability to help nations appearing on request list of ten.
6. Call WINOVR to establish a consignment table representing willingness and ability by identifying the source and counterforce utility to be supplied by each Nation-Group including present location of force. WINOVR then awards alignment and alliance points to offerers on basis of offers.

5. 10. 2 Detailed Description of LIANCE

In TEMPER the force needs of a Nation-Group are computed assuming that Nation-Groups will try to supply force in anticipation of planned action (a change in the level of military operations or an increase in level of deterrent

threat). Thus a plan to increase the level of military operations for a Nation-Group results in an increased level of aid request for the alliance to assume in setting aside possible help for a Nation-Group. If there is a planned decrease in the level of military operations, then in anticipation of this decrease, the Nation-Group will lower his requirement for force. In either the case of increase or decrease in force requirements, the result may not require assistance from the alliance. In the case of the increased need, the Nation-Group may have a surplus to start with. If the surplus is great enough, then the increased requirement may be met with existing forces. If the surplus is not great enough, then there will be a request for force set up for the alliance to meet.

If there was originally a shortage, but the decrease in force requirements resulting from the anticipated decrease in military operations is greater than the shortage, there could be a surplus declared. In the case of a major bloc member, this surplus will be made available to help others. No reduction in requirements will result from a decrease in the level of deterrent threat.

If some Nation-Groups have a surplus of force, the exogenous forces in that Nation-Group will be examined and declared as surplus (available to the owner) and may be committed for shipment to a Nation-Group in need of help. This is not allowed after the force not yet examined reaches the level of force required in the Nation-Group where it is located. Thus it is assumed in TEMPER that exogenous force may be shipped out only if not needed where located. Indigenous force will only be shipped if the need in the Nation-Group is less than the indigenous force there.

The model design provides only for ten needs for military aid to be registered with each bloc each week. The theory provides for supplying alliance needs first, then attending to neutral needs.

A desired increase of force was determined in SHIFT. It is this desire which is incremented in LIANCE to reflect changes required to cover new orders for level of military operations or the higher level of deterrent threat. The incremented desire represents the request for help. If this value is negative, there is an excess.

To determine the size of a request for difference counterforce utility, that portion of the computation of desired counterforce utility which represents a single opponent's contribution is differentiated to determine the slope of the desired counterforce utility versus level of military operations curve at the point representing current level of military operations (see Equation 1.) This slope is then multiplied by the amount of this week's change to determine the increment to be added to the desired force. It is assumed here that the trend for force needs, at the current level of military operations, will prevail and is appropriate for adjusting the current level of force. Thus for increased needs, there is a tendency in the model to over request, but in the case of cutbacks, only to cut back partially. See Figure 5-19.

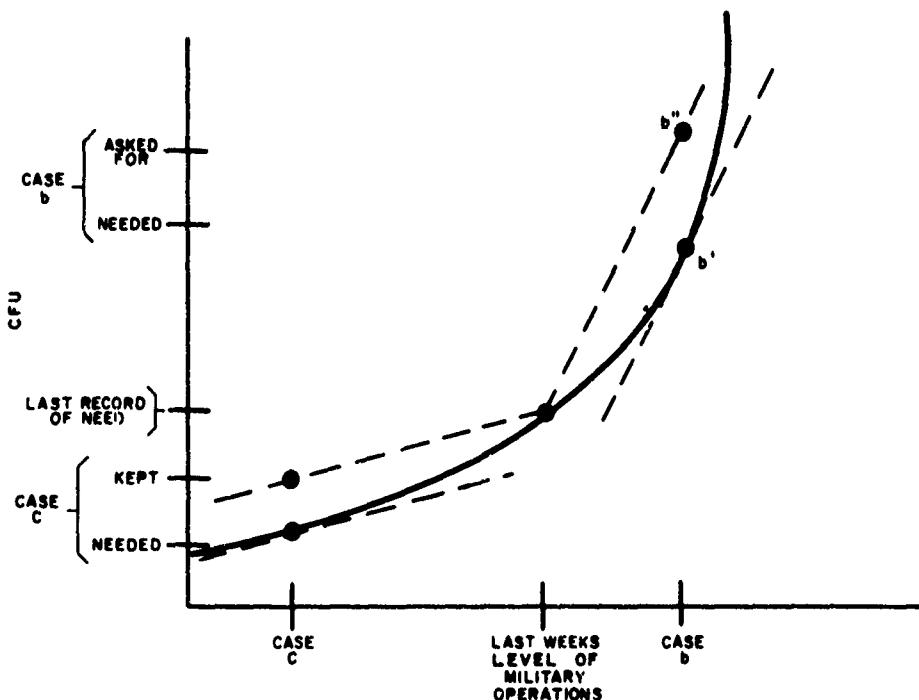


Figure 5-16 CFU Needs Versus Last Weeks Level of Military Operations

The slope of the need-for-force curve is taken at the new military operations level (For the increase this is shown as case b.), on the curve of force needs at point b'. This slope is used to determine the needs to register over and above last weeks needs. Therefore, the slope line is moved to pass through a, the need appropriate for last weeks level of military operations. Reading off this line at b'', the position of the new level of military operations, we may see the force level asked for. This is more than required at b' for the real need. Similarly, it may be shown that by reducing the level of military operations (see Case C), a Nation-Group will keep more than needed.

For each need on which help is requested, certain information is prepared for later use (in XLIANC and WINOVR). For each needy Nation-Group potential helpers are identified. If a Nation-Group has a surplus force (at home or deployed abroad), it is assumed it will be made available if requested by an ally, or neutral, if the needy Nation-Group has awarded alignment or alliance points to the potential helper. For each potential helper, the sum of all surplus exogenous force is determined. Later there will also be a need to determine what percent of a bloc GNP is represented by the GNP of the requesting Nation-Group. Bloc GNP is determined by summing across the members of the bloc.

5.10.3 Equations in LIANCE

1. Request = (Former Desire for Increased Force) +
(Requirements Needed for Anticipated Actions)

where

$$\begin{aligned}\text{Former Desire for Increased Force} &= \text{that computed in SHIFT} \\ \text{Requirements Needed for Anticipated Action} &= (\text{Anticipated} \\ &\quad \text{Change in Operations}) \frac{\text{2 Present Level of Military Operations}}{K}\end{aligned}$$

(K = CFU need coefficient.)

5.11 Subroutine Alliance Control - Extension (XLIANC)

5.11.1 General Description of XLIANC

The XLIANC Subroutine takes the requests from LIANCE and determines how much help it is willing to make available to each Nation-Group on the list of needs.

In performing its functions, XLIANC executes the following events:

1. Identify each potential helper (Nation-Group having surplus force).
2. See which helpers have been awarded alliance or alignment points by the needy Nation-Group.
3. Set the value to the helpers of the needy Nation-Group.
4. Determine proximity between helpers and needy Nation-Group.
5. Set variable STAGE for neutral (memory of past offers to neutral by offerer).
6. Set STAGE for allies (present exogenous force in allies' territory owned by offerer).
7. Compute willingness to help each owner on the list of needs.
8. Compute for each helper, the total willingness to help.

5.11.2 Detailed Description of XLIANC

XLIANC examines each request on the request list generated by LIANCE. For each request, the willingness of each Nation-Group in the alliance to aid the needy Nation-Group is determined and the willingness of each ally to aid all Nation-Groups on the request list is computed.

Before computing a new willingness score, XLIANC assumes that no Nation-Group will supply any help to an ally or to a neutral unless there is a surplus of force. In theory this says that a Nation-Group will always provide resources first to meet needs at home and to cope with problems resulting from contiguous nations. In TEMPER this would be the two Nation-Groups in the potential helping Nation-Group's own conflict region. In effect, no problem is worth considering more than the immediate one, the one caused by a war or potential war threatening a Nation-Group's own territory.

Unless the requestor has awarded alignment or alliance value points to the potential helper, there can be no help. Therefore, if an ally or neutral has been so alienated as to have withdrawn all of its award of points to the potential helper, the helper will punish the requestor by not supplying any aid. A neutral could be so independent that it would withdraw all of its assignment of points, and through this independence find that it had to provide for its needs itself.

The XLIANC Subroutine will force greater attention, and therefore greater willingness to help, on a member of the bloc than on a neutral. The magnitude of this greater emphasis is dependent on the value placed by the helper on the requesting ally. All else being equal, the ally would be given almost fifty percent more attention than a neutral.

In addition to the prejudice in favor of allies, the computation of willingness (see Equation 1) will depend on a modified value of the requestor's need.

A war will substantially magnify the size of the request in the eyes of the supplier. Thus, if the requestor is involved in a war, it will draw on more than its share of available aid. If the size of the requestors problem is changing rapidly, there is a crisis in existence and the request will be slightly magnified over the real need. Otherwise, the alliance will de-emphasize the problem and under supply the requestor. The TEMPER model assumes that all helpers will view a given requestors state of need in this way.

Other factors assumed to be important in arriving at the raw willingness score include the amount of help already being given to the requestor by the potential helper, the geo-political proximity of the requestor to the helper, the geo-political proximity of the requestor to the common enemy, and the share of the bloc GNP represented by the requestors GNP. If a nation is already making a substantial contribution to meet the needs of an ally or neutral, it is felt that there will be a tendency in the future to place more importance on a request from that source than on a nation which does not presently receive aid. Therefore, in TEMPER, this factor is included in the computation of the willingness variable. On a relative basis, the greater the proximity of the requestor to the helper, the greater the willingness to help. However, it is felt that military aid in times of need tends to draw alignment or alliance and therefore the

geo-political proximity of the requestor to the common enemy is given more weight than proximity to the helper. Finally, the economic strength of the requestor is considered. If it is a substantial portion of the economic strength of the bloc, then more attention will be given the request than if it is a small or poor member of the bloc.

5.11.3 Equations in XLIANC

Willingness = (Distortion Factor) (Desired Force) 0.7 [(0.4 (1)
Present Level of Force Being Supplied) + (0.15
Proximity of Needy to Supplier) + (0.25 Proximity
of Needy to Potential Enemy) +
(.2 Needy Nation's GNP
Bloc GNP)] +0.3 Effectiveness of
Needy as Ally

where

Distortion Factor is:

- 1.5 for WAR
- 1.1 for Crisis
- 0.7 for Problem

5.12 Subroutine Winover Through Military Aid (WINOVR)

5.12.1 General Description of WINOVR

In TEMPER, military assistance is offered to allies and to neutrals in response to request of Nation-Groups who need more forces than they possess. Since assistance may be requested only of those Nation-Groups to whom alliance or alignment points are awarded, requests are weighted by the amount of these points in determining offers to be made, and the receipt of consignment is acknowledged by an increase in the amount of points awarded. Requests for military assistance and the willingness of Nation-Groups to help are figured in LIANCE. Actual offers and responses to them are calculated in WINOVR, which is composed of four functions.

- a. The amount of indigenous and exogenous help offered is determined as a function of excess forces available (figured in LIANCE) and the willingness to offer assistance (figured in XLIANC in the WABLE equation).
- b. Consignments are made for the shipment of all force amounts offered which are larger than 0.005 units.
- c. The effect of this military assistance is simulated when political alignment and alliance points are incremented in acknowledgment of aid offered.
- d. The amount of consigned aid is stored so that a record of aid offered by each Nation-Group is maintained.

Since no record is kept of exogenous force deployment to neutral Nation-Groups, this aid cannot be withdrawn, and is therefore offered as a gift. The amount offered is stored. For allies, a record of aid given and received is stored by the Logistics Submodel in the ZMIDZ and ZFMID parameters.

5.12.2 Detailed Description of WINOVR

The TEMPER model simulates the decision to make offers of help to needy allies and neutrals on the basis of the needs developed in LIANCE and the willingness to help as developed in XLIANC. In simulating the construction of a list of offers, TEMPER assumes:

- a. Total offers from all sources will never exceed a Nation-Group's total request.
- b. Offerers will designate all of their surplus forces, both exogenous and indigenous, if requests and willingness to offer to requestors require it.
- c. For a given requestor, the offerer will set aside a prorata share of each available surplus force (i. e., each entry on the Nation-Group's list of deployed forces as well as the home force).

The TEMPER theory is that offers will be made to a nation in need of aid on the basis of the percent of total willingness of the offerer to help the Nation-Group on the list of needs, represented by the willingness assigned to the requestor.

Thus surplus force will be set aside to allow for each requestor to get its fair share of surplus on the basis of the assigned willingness. Each helper will bound this fair share, however, if the total available for offering to a Nation-Group from all sources is more than requested (see Equation 1).

In the case of exogenous force, these may be withdrawn only to the level that leaves enough force to meet the needs of the Nation-Group where the force is located. Thus, the first offerers of help may exhaust the supply of available exogenous force. The order of examining possible offers in TEMPER is arbitrary and a function of the way in which the Data Base is aggregated. Therefore, care should be taken by the user to examine the effect of ordering data on game outcome.

Points of alliance or alignment are awarded on the basis of offers made. These assignments reflect a theory that for a nation an alliance with another nation will become more important if the nation in need receives help from the other nation. The assignment is of the as-yet-unassigned value. This simulates a greater shift for the same amount of help if there is very little present assignment of value, than if there is a presently high assignment. For neutrals there may be assignment to the full value to each Nation-Group so that a neutral may be aligned with Nation-Groups from neither side, or one or the other or both. It is assumed that major bloc members will have no alignment with members of the other bloc (see Equation 2).

5. 12. 3 Equations in WINOVR

1. Assistance = (Amount of Force Available) (Willingness Fraction)

where Amount of Force Available may be the excess at home or a part of an entry on a list of exogenous forces.

Willingness Fraction = helping nation's willingness to aid the requestor/helper's willingness to aid all requestors.

The offer is scaled so that the requestor will receive no more than its request pro rated across all suppliers.

2. Award = (1 - Present Alliance Value) (Tanh (Offer/Request Fraction))

where Present Alliance Value is the value placed by the receiver on the alliance, or, in the case of neutrals, political alignment.

Offer/Request Fraction = amount of offer/total request.

APPENDIX A

GLOSSARY

Alignment Value A relative value which a neutral Nation-Group (the donor) places on the friendship of a bloc member (the recipient). The recipient by offering military aid to, satisfying the consumer demands of, or buying the surplus inventories of the donor can cause the value to rise. If none of these occur, the value gradually declines. See also Ally Value.

Ally Value A relative value which one bloc member Nation-Group (the donor) places on the friendship of another member (the recipient) of the same bloc. The recipient by offering military aid to, satisfying the consumer demands of, or buying the surplus inventory of the donor, can cause the value to increase. If none of these occur, the value will gradually decrease. See also Alignment Value.

Ambiguity A measure of difficulty in obtaining information. Related to "hard" or "soft" data (e. g., GNP easy to get, military information not so easy to get).

Balance of Payments A record of net trade. Since TEMPER is a bartering model trading goods and good will, the balance of payments is increased when exporting and decreased when importing goods.

Basic Counterforce Utility The value in counterforce utility units of a single unit of a given force type. This value is unique to each of the four tactical force types in each of the conflict regions. It is a function of the basic effectiveness of the weapon, the survivability of targets by terrain type, the degradation of weapon firepower as a function of terrain type in a war or terrain distribution during peace.

Basic Firepower Effectiveness An input parameter representing an unmodified effectiveness for each force type against all possible tactical targets.

Bias Simulates the effects that ambiguity, estimation tendency and hostility have on information flow. A Nation-Group will tend to overestimate an opponents potential.

Bloc A group of Nation-Groups which generally act to support one another, and to win the friendship of neutrals. The TEMPER simulation has two blocs generally labeled West and East. See also Bloc Member.

Bloc Leader The Nation-Group so designated for each of the two blocs. It is a strategic owner. It bargains with the opponent bloc leader to reduce strategic spending problems. The other strategic owners in its bloc will model their strategic spending on that of the bloc leader.

Bloc Leader Problem The problem which each bloc leader perceives caused by the spending of the opponent bloc leader for R&D, strategic forces, and tactical forces.

Bloc Member A nation or Nation-Group belonging to either the West or East bloc. It may bargain with the opponent bloc member in its conflict region, and trade with neutrals and its allies.

Bloc Strategic Threat Is a function of the highest level of military operations being directed against any bloc member, and the predicted damage, if there were to be a strategic exchange.

CFU See Counterforce Utility.

Computer Simulation An integrated body of instructions which cause a computer to evaluate in a systematic way formulations which describe a real world system, so as to facilitate numerical analysis of the real world system.

Conflict Region Unless otherwise stated, a geographical subdivision of the TEMPER world land which is any one or more of the following: 1) A West bloc member, 2) An East bloc member, and 3) A neutral. Nation-Groups can only go to war with the other Nation-Groups in its conflict region. May also refer to the sea conflict regions. The TEMPER simulation permits a maximum of 13 land conflict regions, and seven sea conflict regions.

Cost Effectiveness The ratio of counterforce utility per unit of a force type in a given situation to the cost associated with a unit of force. A comparative measure used to select between force types. It is a function of both the force type and the terrain on which the force is to fight. Cost sometimes includes the cost to ship.

Counterforce Utility A measure of the effectiveness of a tactical force in combat. It is a function of the force type, the terrain on which it is to operate, and the size of the force.

Covert Information Information received through intelligence or other covert sources. It may not be forwarded to its intended source, but when received is treated with only partial credibility, modifying rather than replacing former information.

Defense Spending Propensity A relative measure of the fraction of government spending which a Nation-Group will devote to military purposes, all other things being equal. Also called military spending propensity. See also Motivations.

Defense Advantage An advantage for the retreating forces which reduces the vulnerability of those forces. In TEMPER this is a fraction of one-half (or a multiplier twice the survivability). The result is a 2:1 advantage of retreating forces over advancing forces.

Degradation See Degradation Parameter.

Degradation Parameter A set value giving the relative degradation of firepower (kill potential) for each tactical force type in each of three types of terrain.

Desired Land That fraction of its conflict region which at a given moment a Nation-Group will strive to occupy within the limits imposed by the resources and motivations of itself and the two other Nation-Groups in the conflict region. The amount desired may be larger or smaller than the amount actually occupied.

Deterrent Threat Also called verbal threat, threatened motivation, etc. A measure of the level of military operations by the opponent Nation-Group which the subject Nation-Group has threatened to retaliate against. See also Military Operations.

Distortion The result of combining the effects of Bias and uncertainty to simulate perception. Uncertainty includes probability of receiving covert or overt information influenced by using a statistical measure.

Disutility The quality of causing inconvenience, discomfort, or pain, opposite of utility. In TEMPER represented in a variable, UTILITY, computed in Subroutine CDALC. Measures the inconvenience, costs, etc. of a given war to a Nation-Group. Not to be confused with UTLTY or UTIL computed in WINIT.

Estimation Tendency A measure of underestimation or over-estimation of classes of data.

Exogenous Force A tactical land force located in a Nation-Group other than its own. Each force is identified as to its type, owner, and the Nation-Group in which it is located. See also Tactical Forces, Military Aid.

External Dynamism For neutrals, a measure of independence or nationalism and for bloc member also a relative measure of the energy with which a Nation-Group pursues its external goals. See also Motivation.

Firepower Degradation In wartime the value of the degradation parameter for the weapon type in the terrain where the war is being fought. In peacetime, the weighted sum of the values of the degradation parameter for all three terrain types. Weighting is by percent of each terrain type in the conflict region of interest.

Force Vulnerability In wartime 1/survivability parameter, value for the weapon type in the terrain where war is being fought. In peacetime, the weighted sum of the values of 1/survivability for all three terrain types. Weighting is by percent of each terrain type in the conflict region of interest.

Friendship Value A general term meaning both Ally Value and Alignment Value.

Global Threat (Political) A threat felt resulting from allies is a function of the value placed on the alliance with the ally, and the tactical threat to which the ally is subjected. This is summed across all allies for each member of the bloc.

Hostility A measure of animosity that a Nation-Group feels for an opponent. Weekly tactical hostility has the following components:

- a. Perceived land desires of conflict region opponent.
- b. Military coercion
- c. Military initiative
- d. Tax rate
- e. Tactical threat

Weekly tactical hostility is "felt" by all Nation-Groups. Strategic hostility (quarterly) is felt by bloc leaders; USA and USSR. It is a function of political alignment changes and strategic threat.

Internal Initiative See Reinvestment Propensity.

Land Conflict Region See Conflict Region.

Major Bloc Member See Bloc Member.

Military Aid The furnishing of tactical land forces to an ally or neutral in need of help. See also Exogenous Force.

Military Coercion Also military coercion propensity. A relative measure of the willingness of a Nation-Group to use its military forces to reduce the size of its problems. See also Motivation.

Military Forces The tactical, strategic, and naval forces of a Nation-Group.

Military Initiative See Defense Spending Propensity.

Military Operations A numerical measure of the level of military operation that one Nation-Group is conducting against another in its conflict region. May range from none through reconnaissance, limited war, general war to nuclear war. See also Deterrent Threat.

Military Pressure to Neutral See Pressure.

Military Threat Felt by a nation is a weighted sum of the tactical and strategic threats.

Military Power Ratio Motivation The ratio of own to opponent spending for R&D, strategic, or tactical force which the Nation-Groups of a bloc view as ideal.

Model An integrated body of formulations which describe the operation of a real world system.

Motivation Five standards of conduct, military coercion propensity, external dynamism, re-investment propensity, defense spending propensity, and taxation propensity, which a Nation-Group uses in part to guide its actions. Taken as a group, the five motivations describe the underlying character of the Nation-Group. See also Military Power Ratio Motivation.

Motive A static value representing the value for motivation toward which a nation tends in the absence of threat. It is used for four motivations:

- a. Military Coercion Propensity
- b. Reinvestment Propensity
- c. Defense Spending Propensity
- d. Taxation Propensity

Nation-Group The national entity which in the TEMPER simulation takes the place of one or more real world nations. It will embody the characteristics of its real world constituents.

Naval Forces Also called naval surface forces. Conventional naval forces of homogenous composition which engage one another, shipping, and SLBM subs in the sea conflict regions. Each force is identified as to its size, owner, and the sea conflict region in which it is located.

Neutral Nation or Nation-Group A nation or Nation-Group not a member of either the East or West blocs. It awards alignment value to bloc members whose friendship it values. It does not bargain. It does not trade with other neutrals.

Object Nation-Group The Nation-Group which at a particular moment is being treated by the simulation in relationship to the subject Nation-Group. Since the simulation can only operate sequentially, if a function is to be performed for a number of Nation-Groups in relationship to the subject Nation-Group, each in turn will be made the object Nation-Group by the simulation.

Overt Information Information available from normal open sources. More available about the United States than about the Soviet Union, it is taken as credible and replaces former information.

Perception A distorted value of a quantity associated with a specific Nation-Group which is used by another Nation-Group in lieu of the actual value to simulate real world errors in data transmission and data evaluation.

Political Pressure to Neutral See Pressure.

Political Threat Felt by a Nation-Group is a sum of the bounded components, global political threat, political threat from neutrals, and political threat from allies.

Political Threat From Allies Is a function of both the present value placed on a nation by its allies and the amount of value that the allies have withdrawn. For each member of the bloc this is summed across all its allies.

Political Threat From Neutrals Summed for each bloc member across all neutrals, is a function of the present value placed on the nation by the ally, and the amount of value withdrawn.

Pressure There are two kinds of pressure to a neutral, military and political. Military pressure is a function of neutrals' perception of an opponent's land desire and the tactical threat the opponent poses. Political threat is a function of how much alignment the neutral assigns over that allowed for his degree of independence.

Problem The discrepancy which a Nation-Group measures between an actual condition and what it views as the ideal condition. It will attempt to reduce the problem size. See also Weekly Problems, Bloc Leader Problem.

Quarter A quarter of a TEMPER year which is equal to twelve TEMPER weeks. Most quarterly functions occur on the last or twelfth week of the quarter.

Reinvestment Propensity A relative measure of the fraction of GNP which a Nation-Group will invest in capital goods, all other things being equal. See also Motivations.

Sea Conflict Region One of the geographical subdivisions of the real world oceans used in the TEMPER simulation. The naval forces of the Nation-Groups are deployed to specific sea conflict regions. See also Conflict Region.

Sector, Economic One of the six parts into which the economy of each Nation-Group is divided. These are: 1) military, 2) light industry or consumer goods, 3) heavy industry or capital goods, 4) agriculture, 5) resources development, and 6) services.

Shipping Channel See Transportation Units.

Shipping Units See Transportation Units.

Strategic Forces The four basic force types into which strategic forces are divided are: 1) hidden land missiles (ICBM's), 2) located land missiles (ICBM's), 3) SLBM equipped submarines (also called offensive submarines), and 4) strategic aircraft wings, e.g., B-52's. See also Strategic Owner.

Strategic Threat Is the strategic threat to the bloc modified by the credibility of that threat.

Strategic Owner A bloc member Nation-Group which possesses one or more of the four strategic weapon types. It will include strategic spending in its budget and be responsive to the spending policies of its bloc leader. The TEMPER simulation allows for a total of six strategic owners, two of which are also bloc leaders.

Subject Nation-Group The Nation-Group which at a particular moment is being treated by the simulation. Since the simulation can only operate sequentially, if a function is performed for each of the Nation-Groups, the simulation will make each in turn the subject Nation-Group. See also Object Nation-Group.

Subroutine A discreet portion of the computer program which can be handled as a separate entity. It generally consists of one or more related simulation systems or handling system functions.

Survivability See Survivability Parameter.

Survivability Parameter A set value giving the relative survivability of each tactical force type in each of three types of terrain.

Tactical Forces Also called tactical land forces. The four basic force types into which all non-strategic forces are divided: 1) tactical aircraft wings, 2) conventional army divisions (also called ROAD divisions), 3) paramilitary groups, and 4) nuclear armed army divisions. In the context of spending, generally includes naval as well as land forces.

Tactical Threat Is felt by one nation as a directed threat from an opponent and is a function of the ratio of counterforce utility owned and perceived by the nations, and the level of military operations being conducted.

Taxation Propensity A relative measure of the willingness of a Nation-Group to impose additional taxes to reduce the size of a problem, all other things being equal. See also Motivations.

Threat There are two kinds of threat, military and political. Military threat* has three components:

- a. bloc strategic threat*
- b. tactical threat*
- c. strategic threat*

Political threat* has three components:

- a. global political threat*
- b. political threat from allies*
- c. political threat from neutrals*

Neutrals are subjected to a form of threat called pressure*. There is political threat to neutrals and military threat to neutral. Total threat is a weighted sum of political and military threat.

Threshold A numerical quantity with which a variable is compared to determine the course of action. For example, the potential gain or loss of a war for a Nation-Group is compared with a particular threshold to determine if the Nation-Group should escalate, de-escalate, or maintain the status quo.

Trade Command The amount of demand which the Nation-Group may attempt to satisfy through trade in each of the four tradable sectors of the economy.

Trade, Political Exports by a Nation-Group from its surplus inventory to satisfy the matching consumer demands of Nation-Groups which have decreased the value they have awarded to the exporter. The exporter conducts the trade to regain the lost friendship. See also Trade, Residual and Friendship.

Trade, Residual Imports to satisfy consumer demand by a Nation-Group from Nation-Groups that both have awarded it friendship value, and have match surplus inventory. See also Trade, Political and Friendship.

*See Glossary entry for definition.

Transportation Units Also called shipping units. The simulated inventory of ships owned by a Nation-Group with which it can ship military forces to other Nation-Groups. Each such shipment is recorded in what is called a shipping channel, which in effect is a bill of lading or cargo manifest. Both transportation units and a free shipping channel must be available to a Nation-Group if it is to make a military force shipment.

Variable A quantity which describes a specific element of the TEMPER world, e.g., the annual GNP of a specific Nation-Group, which is capable of changing in value during a game run. The TEMPER simulation includes several thousand variables.

Verbal Threat See deterrent threat.

Vulnerability The reciprocal of survivability, i.e., $1/\text{SURVIVABILITY}$.

WAR NUMBER A number assigned to a war in a conflict region. It uniquely identifies the two blocs involved in the war by identifying the number of the blocs not involved. Thus, a Type 2 war would be between blocs 1 and 3, or West and neutral respectively (in present Data Base).

Week The smallest division of time in the TEMPER world. It is represented by one cycle of the simulation whose functions are designed to represent the activities of a real world week during each iteration.

Weekly Problems The total of eight problems which each Nation-Group perceives are caused by the other two Nation-Groups in its conflict region. These problems are: 1) military operations, 2) deterrent threat, 3) difference in size of tactical forces, and 4) desired fraction of the conflict region land. The size of each problem is recomputed each TEMPER week for each Nation-Group.

Year The TEMPER simulation of a real world year; it is equal to forty-eight TEMPER weeks or four TEMPER quarters. Most annual functions occur on the last week of each year.

117 Nations Usually a reference to list of 117 nations as of 1 January 1965 on which the Data Base operational on 1 July 1965 is based. The list is intended to include the entire real world.

SUPPLEMENTARY

INFORMATION

AD 4714584



THE JOINT CHIEFS OF STAFF
WASHINGTON, D. C. 20301

JOINT WAR GAMES AGENCY

JWGA- 180467
8 MAY 1967

MEMORANDUM FOR USERS OF TEMPER MODEL DOCUMENTATION

Subject: TEMPER

Users of this material are advised that the TEMPER model is an experimental and rudimentary effort to apply computer technology to the simulation of international relationships. The current JWGA goal in follow-on activities to TEMPER is to develop a broad base of international affairs theory and salient factors relevant to conflict relationships, elements of which might be computerized to reinforce interagency activities in the field of simulation and gaming. There is no expectation that TEMPER will be developed into a practical tool either for analyzing international affairs problems per se or providing insights into crisis management. The TEMPER model, as now constituted, can best be used as a reference to assist in future development thru examination of its deficiencies.

A handwritten signature in black ink, appearing to read "James D. Kemp".
JAMES D. KEMP
Brigadier General, USAF
Chief, Joint War Games Agency

JOINT WAR GAMES AGENCY

JWGA-180A67

8 May 1967

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Brigadier General, USAF
Chief, Joint War Games Agency

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JWGA- 110-67

8 MAY 1967

MEMORANDUM FOR THE ADMINISTRATOR, DEFENSE DOCUMENTATION CENTER, CAMERON STATION, ALEXANDRIA, VIRGINIA 22314

Subject: Preface for TEMPER Documentation Volumes

1. The Joint War Games Agency, Organization of the Joint Chiefs of Staff, has release authority over the below-listed TEMPER model documentation volumes:

<u>Volume</u>	<u>DDC AD Number</u>
I	470375
II	471458
III	470241
IV	473050
V	470069
VI	470070
VII	470071

2. It is requested that the attached memorandum be included with each order for this material from DDC users.

JAMES D. KEMP
Brigadier General, USAF
Chief, Joint War Games Agency

Attachment
a/s

JOINT WAR GAMES AGENCY

JWGA- 180367

3 MAY 1967

MEMORANDUM FOR USERS OF TEMPER MODEL DOCUMENTATION

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JAMES D. KEMP
Brigadier General, USAF
Chief, Joint War Games Agency



THE JOINT CHIEFS OF STAFF
WASHINGTON, D. C. 20301
JOINT WAR GAMES AGENCY

JWGA- 389-67

3 NOV 1967

AD-471458

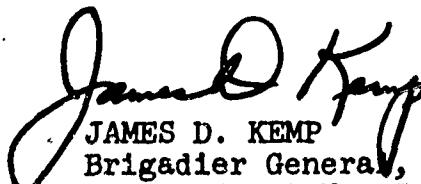
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MEMORANDUM FOR THE ADMINISTRATOR, DEFENSE DOCUMENTATION CENTER, CAMERON STATION, ALEXANDRIA, VIRGINIA 22314

Subject: Preface for TEMPER Documentation Volumes

1. Reference is made to JWGA memorandum 180-67, dated 8 May 1967 with attachment.
2. By reference memorandum, it was requested that a statement concerning the nature and status of the TEMPER model be made a part of the seven volumes of TEMPER documentation listed below.
3. It is requested that the attached statement be substituted for the statement of reference memorandum in order that users of this material may have the benefit of two excellent evaluation reports on the model.

<u>VOLUME</u>	<u>DDC AD #</u>
I	470375
II	471458
III	470241
IV	473050
V	470069
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VII	470071


JAMES D. KEMP
Brigadier General, USAF
Chief, Joint War Games Agency

Attachment
a/s



THE JOINT CHIEFS OF STAFF
WASHINGTON, D. C. 20301
JOINT WAR GAMES AGENCY

JWGA- 350-67

6 NO. 367

MEMORANDUM FOR USERS OF TEMPER MODEL DOCUMENTATION

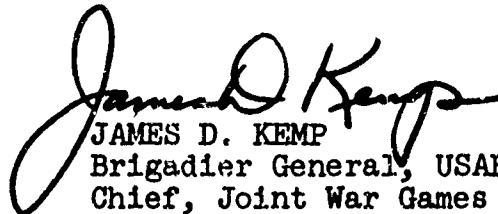
Subject: TEMPER

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2. In order that users of this material obtain a balanced and comprehensive view regarding the capabilities and limitations of the model, it is recommended that the following two independent evaluation reports be carefully considered:

a. MATHEMATICA Corporation, Review of the TEMPER Model, September 30, 1966; DDC AD # 816457.

b. SIMULMATICS Corporation, TEMPER as a Model of International Relations, December 1966; DDC AD # 653606.


JAMES D. KEMP
Brigadier General, USAF
Chief, Joint War Games Agency